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# FRANKFORD ARSENAL

REPORT NO. R-1166



STEEL AP PROJECTILES - CONVENTIONAL, TREATMENT

ARMED FORCES RESEARCH CENTER REPORT

BY

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PROJECT TA1-5002

PICMAN-DUNN LABORATORIES

FRANKFORD ARSENAL

PHILADELPHIA, PA.

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**REPORT R-1166**

**SOLID STEEL AP PROJECTILES - CONVENTIONAL, TRUNCATED  
AND TIPPED TRUNCATED OGIVAL TYPES**

**Project TAi-5002**

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**OBJECT**

To compare systematically the performance of conventional, truncated and tipped truncated ogival projectiles over a wide range of target conditions.

**SUMMARY**

The armor penetration performance of 20 mm models of the 90 mm AP T33 (M318) projectile has been compared with that of the truncated T33 (FAP)\* and the tipped truncated T33 (FAPT)\* projectiles over a wide range of target conditions. These conditions included: 3/8 (0.48 cal), 1/2 (0.63 cal), 5/8 (0.79) cal, 3/4 (0.95 cal), 7/8 (1.11 cal), 1 (1.27 cal), 1 1/8 (1.43 cal) and 1 3/8 (1.75 cal) inch homogeneous (300 to 320 Bhn) armor set at 0°, 30°, 45°, 55°, 60° and 70° obliquities. Specific limit energies\*\* were calculated for all protection ballistic limits. By this means, the perforation efficiencies of the three projectile types could be compared on an energy basis for any test, regardless of nose shape or projectile weight.

Against targets that FAP projectiles defeated intact they were superior to the AP and FAPT types. The superiority of the FAP over the AP on an energy basis ranged from 20 to 60 per cent. The intact FAP were superior to the other two types for all plate thicknesses up to 3/4 inch at 30° and 45° obliquities, for all plate thicknesses up to 5/8 inch at 55° and 60° obliquities, and for 3/8 inch plate at 70° obliquity. However, the FAP were barely able to defeat 5/8 inch plate at 0° without shattering. Against heavier targets the FAP shattered and were much inferior to the FAPT and AP.

The FAPT (tipped) projectiles were superior to the FAP when the latter shattered. However, when both types remained intact, the FAPT were inferior to the FAP. The FAPT were equal to or superior to the AP for almost all of the target conditions investigated. Exceptions were heavy plate at 0° obliquity and thin plate at intermediate obliquity. FAPT projectiles were superior to the AP against armor up to and including 7/8 inch thickness at 55° and 5/8 inch at 70° obliquity. For the more difficult high obliquity targets, the FAPT and AP types appeared to be equal in performance.

Conventional AP projectiles were best in the limited region of very heavy plate at very low obliquity.

Some of these 20 mm penetration results have been confirmed by limited firings of truncated 75 mm AP M338 (T148) shot,<sup>(1)</sup>\*\*\* truncated conical 120 mm AP T116E2 shot<sup>(2)</sup> and tipped truncated 76 mm AP T166 shot. In addition, preliminary results have been

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\*These notations are not official Ordnance designations but have been used for easy reference.

\*\*Specific limit energy is defined in the first section of Results and Discussion.

\*\*\*See Bibliography attached.

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obtained by the US Naval Proving Ground in a program sponsored by the Army Ordnance Department to provide a systematic comparison of the regions of superiority of the AP, FAP and FAPT types with three-inch shot homologous to the 20 mm models. These limited firings indicate that full caliber shot of these types can be made to show the same relative penetration performance if adequate shot hardness and ductility are provided.

The foregoing results have shown the usefulness of each one of the projectile designs for defeat of certain steel armor targets. It is recommended that the truncated designs also be considered for other missiles, such as shells, rockets, and bombs, which may be made of steel or other materials. Furthermore, it is believed that the truncated types should be investigated for defeat of light alloy aircraft armor at very high obliquities.

**AUTHORIZATION**

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**INTRODUCTION**

These tests are part of a general program to develop an improved armor-piercing projectile for use against sloping homogeneous armor at high obliquity. When this program was initiated, it was recognized that neither the ogival headed monobloc nor the capped projectile is the most efficient design for defeating armor at large angles of attack (greater than 50°). Under these conditions the monobloc projectile breaks up or ruptures and its energy is dissipated and wasted over a fairly large area. However, in rupturing it defeats the plate by a punching process and it is much more efficient<sup>(3)</sup> than capped projectiles whose bodies tend to remain intact and ricochet. In ricochet, so little of the energy of the shot body is used for plate perforation that the capped projectile is worse under these conditions. It was believed, therefore, that the problem in seeking a better design was primarily one of preventing ricochet.<sup>(4)</sup>

Early in World War II the Naval Proving Ground demonstrated the ability of a flat-ended cylindrical projectile to dig in and to cause plate failure by punching<sup>(5)</sup> with very little adverse turning. For conditions where it remains intact, at velocities up to about 1500 fps, the cylindrical projectile is much superior to a conventional ogival one in defeating thin plate. However, at higher velocities and against thicker plate this projectile breaks up. As a result, its penetrating ability usually is worse than that of the conventional projectile.

Modification of the cylindrical shot by tapering the body near the "biting edge" increases its useful velocity range at high obliquity by raising its rupture velocity almost 1000 fps. Hence, it is able to defeat thicker plate. This shape is usually made by truncating a conventional projectile.

A second modification, attachment of a tip (in the form of an ogive) to the truncated projectile, further increases its effective range several hundred feet per second. This tip has a flat larger than that of the shot body since it appears that the overhanging flat gives more protection to the "biting edge" of the body and, hence, raises the velocity at which rupture occurs.

From preliminary firing it was noted that the tipped projectile is a better projectile than the conventional monobloc for some conditions of attack. However, little was known of its behavior either at velocities above 3200 fps or at low and intermediate (less than 50°) angles of obliquity where it was thought that the monobloc projectile might be superior.

The primary purpose of this investigation is to compare systematically the performance of the conventional AP projectile with that of the new unconventional FAP and FAPT types over a wide range of target conditions. Comparative data of this sort

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\*Striking velocity at which projectile failure is first observed.

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should evaluate the potentialities of the new designs, define the conditions under which each is superior, and facilitate testing of other modified designs expected to be capable of even better all around performance.

**MATERIALS**

**Projectiles**

**Types.** Three types of 20 mm projectiles were used in this survey. They were: (a) 20 mm model of the 90 mm AP T33 (M318), (b) truncated T33 (FAP) and (c) truncated T33 with a tip attached (FAPT). Drawings and photographs of these projectile types are included in Figures 1 and 2, respectively.

The conventional AP T33 projectile was chosen as a standard because it shows good ballistic performance at high obliquity. This design is used also for the 105 mm AP T182 and the 120 mm AP T116 projectiles and is similar to the 76 mm AP T128 projectile. It has been thoroughly tested and its average performance is fairly well known (e. g., Watertown Arsenal caliber .40 and 90 mm tests). The weight of the 20 mm AP projectiles used in this test was 1800 grains.

FAP projectiles were made by truncating the AP projectiles to a flat diameter of 0.650 inch. These projectiles weighed 1680 grains. FAPT projectiles were made by brazing\* tips to the nose flats of the FAP projectiles. These tips had the shape of the AP ogive with a flat diameter of 0.720 inch. The FAPT projectiles weighed 1880 grains.

Although other projectile nose flat and tip flat combinations might be just as effective, the 0.650 inch body flat and 0.720 inch tip flat were chosen for several reasons. A 0.720 inch diameter tip flat on a 20 mm projectile corresponds to the largest flat on full scale projectiles that easily permits windshield attachment to the shot body. Furthermore, previous firings indicated that the tip should overhang the body nose flat to better protect its biting edge and the body flat should be as large as possible without being susceptible to rupture.

**Steel and Heat Treatment.** One heat of manganese-molybdenum steel (Fed Spec 57-107-33) was used for all projectiles. The composition is contained in Table I.

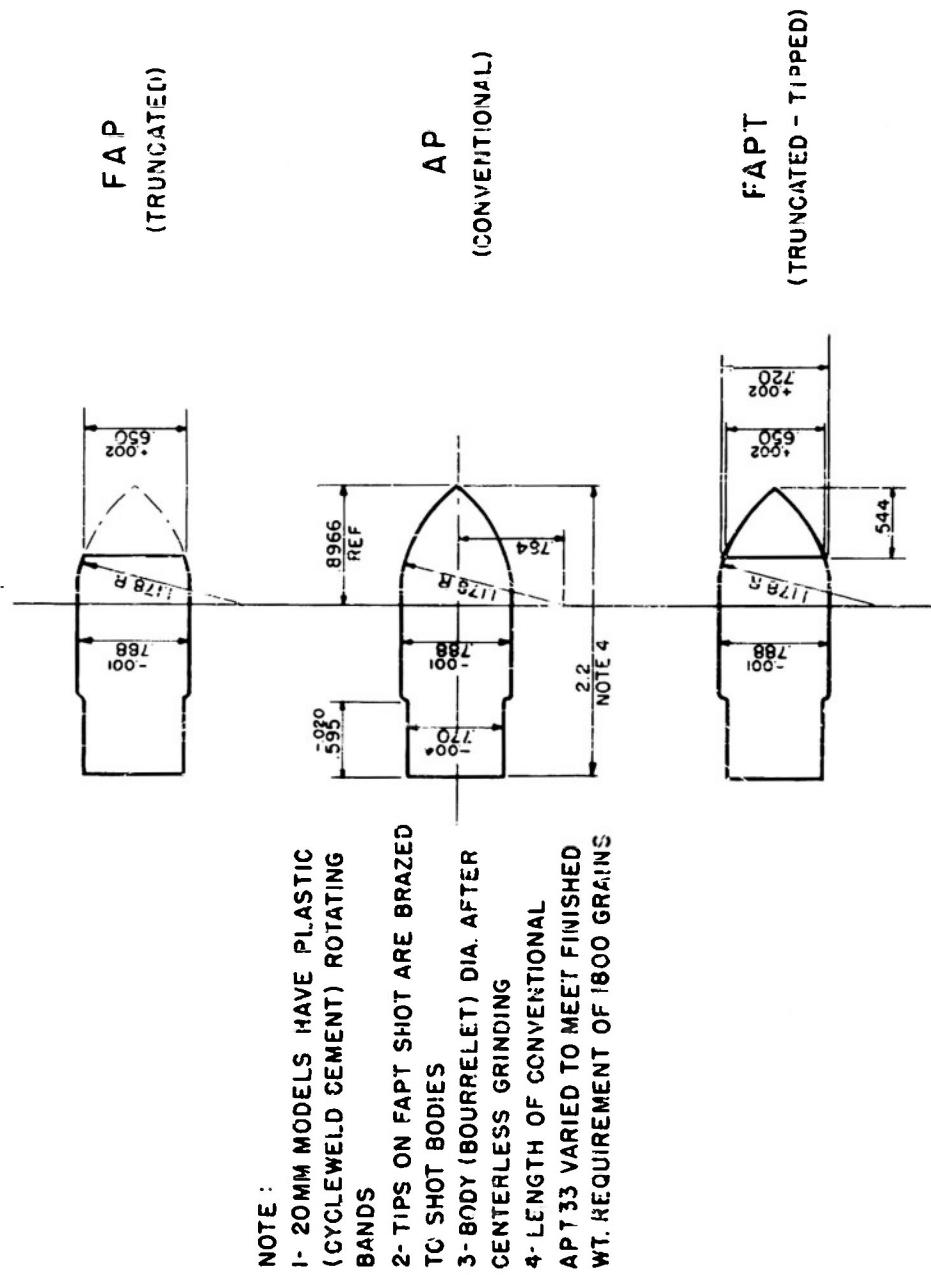
Table I. Per Cent Composition

C	Mn	Mo	P	S	Si	Ni	Cr	V
0.74	0.90	1.04	0.20	0.04	0.33	0.05	0.15	0.02

\*Copper was used as a brazing material.

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Figure 1. 20 mm A.P. shot types

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To obtain consistent quality for the three types of projectiles all shot were run through the controlled atmosphere furnace that was used to braze the tips for the FAPT projectiles. The temperature of the furnace was about 2050° F.

Following exposure to this elevated temperature and cooling to room temperature, all projectiles were austenitized in salt at 1550° F for 10 minutes, quenched in brine, stress relieved for two hours at 250° F and base drawn by induction.

Rotating Bands. To avoid degradation of the shot and difficulty of interpretation of results due to possible quench cracks in the band seat region, all projectile bodies were machined without band seats. Instead of copper rotating bands, all shot were provided with Chrysler Cycleweld C-14 cement rotating bands applied to a 0.60 inch long base section of 0.770 inch diameter. Although a slight loss in velocity and accuracy resulted from the use of these rotating bands, it was believed that reduction of projectile band seat failures would outweigh these drawbacks.

**Plate**

All plates used in this investigation were rolled homogeneous (class B) armor. Brinell hardness values and Charpy impact values (-40° F) for the various plate thicknesses are included in Table II.

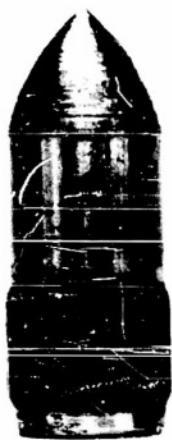
**Table II. Plates Used in Tests**

<b>Thickness (in.)</b>	<b>Plate (No.)</b>	<b>Hardness (Bhn)</b>	<b>Charpy Impact* (ft-lb at -40° F)</b>
3/8	13	302-321	27
3/8	14	302-321	27
1/2	23	302-311	-
5/8	21	311-311	15
5/8	22	302-321	15
5/8	29	311-311	15
3/4	34	302-302	12
3/4	43	302-302	12
7/8	47	302-306	21
7/8	48	302-311	21
1	26	302-302	17
1 1/8	15	311-321	23
1 3/8	7	310-330	19

\*The values listed are not those for the plates listed but are for other plates of the same thickness and heat of steel.

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AP



FAP



FAPT

Figure 2. 20 mm shot types

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**METHODS**

**Test Conditions**

The test conditions listed in Table III were chosen to give information over a wide range of attack. They bracketed nearly all conditions proposed for full scale test firing. Emphasis was on high angle attack but tests also were conducted at low angles for completeness. Conditions for which perforation is difficult at the highest velocities attainable with the special test weapon, and conditions for which the FAP projectile perforates intact are included. Target conditions were spaced at fairly close intervals so that interpolation between experimental results would be feasible. For some targets only limited firings were conducted so that more test conditions could be investigated. Additional test conditions were added during the investigation in order to aid interpolation and to permit the construction of reasonable perforation curves.

**Table III. Test Conditions**

<i>Piste Thickness (in.)</i>	<i>(cal)</i>	<i>Oblliquity (deg)</i>
3/8	0.48	45, 55, 60, 70
1/2	0.63	45
5/8	0.79	0, 30, 45, 55, 60, 70
3/4	0.95	30, 45, 55, 60
7/8	1.11	30, 45, 55, 60
1	1.27	0, 45, 55
1 1/8	1.43	30, 45
1 3/8	1.75	0

**Firing**

All rounds were fired from a 20 mm Mann type test barrel chambered for the T20 (.60/20 mm) case. For velocities in excess of 3000 fps a special chamber extension was screwed onto the above barrel to accommodate a two-piece, double length case. The distance from the muzzle of the gun to the plate was 215 feet. Velocities were measured on counter chronographs actuated by three pairs of solenoids, the base line centers of which were 32, 87 and 132 feet from the plate. Three pairs of solenoids were used to obtain measurements of the projectile retardation between the centers of the three base lines. These retardations then were used to correct the instrument velocities to the actual striking velocities.

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**Evaluation**

**Protection Ballistic Limit.** Protection ballistic limits\* were usually obtained with not more than 50 fps between the velocities for the highest partial and lowest complete penetrations. In order to obtain a ballistic limit when a zone of mixed results was obtained, the velocities for the partial and complete penetrations within the zone were averaged.

If a shatter gap\*\* with AP or FAPT projectiles was suspected, an attempt was made to establish its existence and to obtain ballistic limits with both intact and shattered projectiles.

To avoid misinterpretation due to differences in weights among the three types of projectiles the specific limit energies\*\*\* were determined for all ballistic limits and used for all comparisons of the three types.

**RESULTS AND DISCUSSION**

**Correlation with Watertown Arsenal Firings**

Watertown Arsenal has conducted fairly extensive firings with caliber .40 models of the 90 mm AP T33 projectile over a range of attack conditions comparable to those in this investigation. In order to determine the extent of agreement between the Frankford Arsenal results at the 20 mm scale and the Watertown Arsenal results at the caliber .40 scale, and to establish the most representative penetration curves, the caliber .40 results (Table IV)\* were scaled to 20 mm and were compared with the 20 mm results. The results at both scales are plotted in Figure 3. A scale factor of 0.937 was used to reduce the specific limit energies of the Watertown Arsenal results to compare with the 20 mm results. Using this scale factor, Watertown Arsenal's and this arsenal's results are in excellent agreement, except for plates 1/2 caliber thick which the caliber .40 projectiles perforated intact, whereas the 20 mm projectiles shattered. Excessive ricochet of the caliber .40 projectiles, resulting from the fact that they remained intact, would account for the higher limits of these projectiles. It should be noted that in the family of curves in Figure 3 the curves for 40°, 45°, 50°, and 55° obliquities were drawn by means of interpolation since the 40° and 50° data were obtained by Watertown Arsenal, whereas the 45° and 55° data were obtained by Frankford Arsenal.

\*Defined according to Ordnance Department Bulletin No. 24-44.

\*\*A shatter gap is a velocity range in which shattered or ruptured projectiles fail to defeat the target. At velocities below this range projectiles that remain essentially intact defeat the target and at velocities above this range shattered projectiles defeat the target.

\*\*\*Specific limit energy is defined in the following section.

\*Data obtained by personal communication with Watertown Arsenal Laboratory.

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Table IV. Summary of Watertown Arsenal Caliber .40 Firings

Plate Thickness Caliber In.	0°			30°			Plate Obliquity			50°		
	A	B	C	A	B	C	A	B	C	A	B	C
1.75 0.7	2710	3.88	3.64	4028	8.55	8.02	4335	9.96	9.28	4998	13.16	12.33
1.50 0.6	2400	3.04	2.85	3490	6.43	6.02	3842	7.78	7.29	4414	10.29	9.64
1.25 0.5	2125	2.38	2.23	2934	4.54	4.25	3180	5.33	5.00	3581	6.78	6.35
1.00 0.4	1846	1.80	1.69	2407	3.15	2.96	2594	3.55	3.32	2875	4.36	4.09
0.75 0.3	1558	1.28	1.20	1682	1.49	1.40	1968	2.04	1.91	2366	2.99	2.80
0.50 0.2							1270	0.85	0.80	1699	1.52	1.42
55°			60°			65°			70°			
1.75	5360	15.18	14.23	5610	HP							
1.50				5105	13.76	12.90	5680	HP				
1.25				4348	9.96	9.34	4908	12.70	11.91	5618	16.62	15.58
1.00				3495	6.43	6.02				4622	11.25	10.54
0.75				2866	4.33	4.06				3757	6.47	6.07
0.50				2568	3.47	3.25				3125	5.14	4.82

A - Protection ballistic limit f/s

B - Specific limit energy  $10^6 \frac{\text{lb. ft}^2}{\text{in.}^3}$

C - Specific limit energy scaled to 20 mm

HP - High partial

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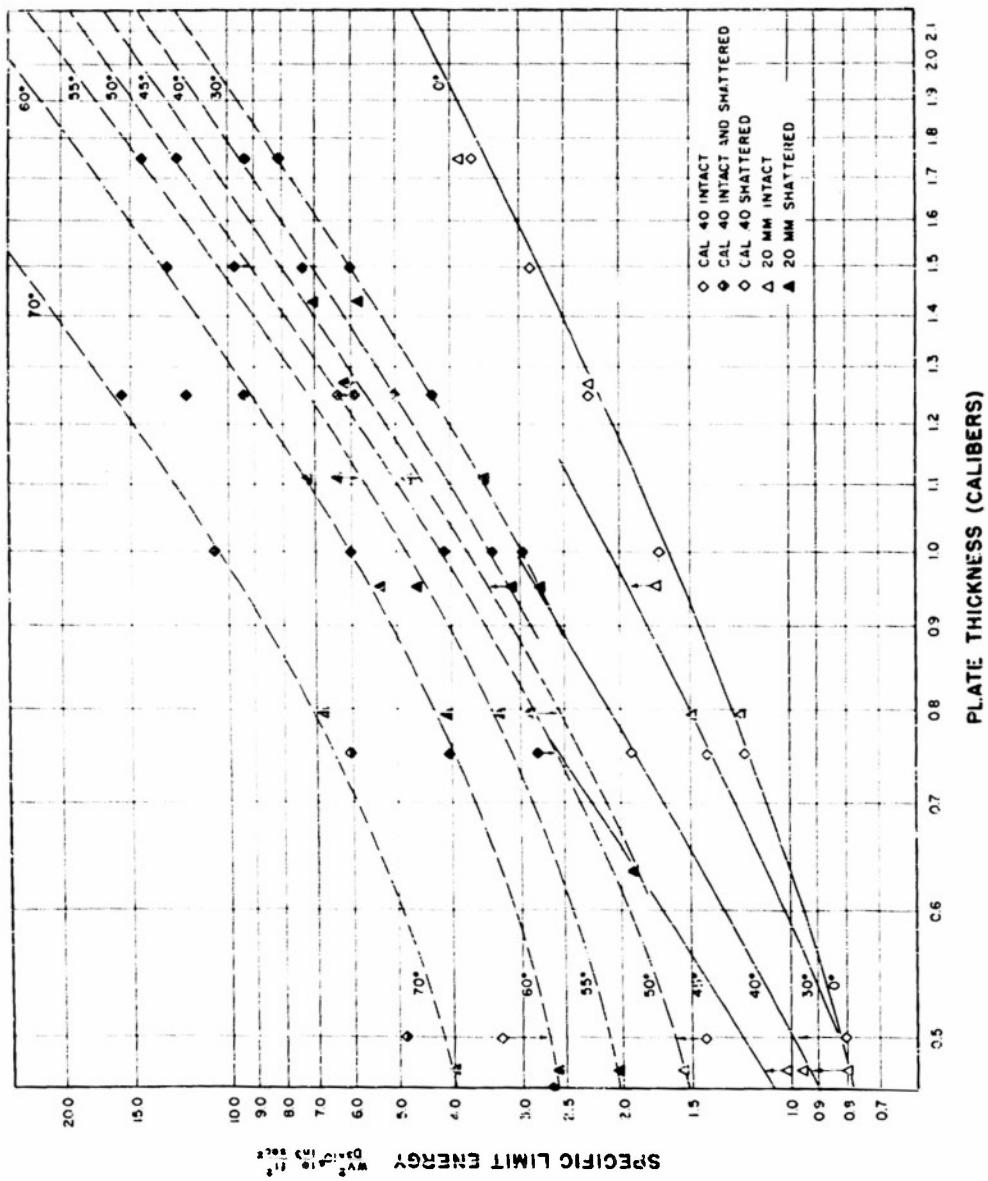


Figure 3. Correlation of Watertown Arsenal caliber .40 AP T33 and Frankford Arsenal 20 mm AP T33 firings

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**A**

PP at 1775 fps SI



**B**

CP at 1825 fps SI



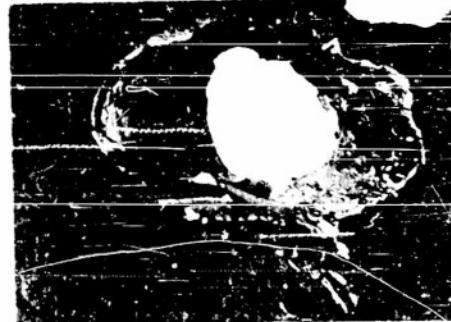
**C**

CP at 1933 fps SI



**D**

PP at 2021 fps S Sh



**E**

CP at 2320 fps S Sh

Figure 4. AP vs 3/4 F-43 at 30° showing shatter gap

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The curves for intact projectiles were drawn according to the following formula which was developed by the National Physical Laboratory, England, for angles of attack up to 45°.

$$\frac{WV_L^2}{d^3} = \left[ 43.4\sqrt{B} \frac{t}{d} \sec \frac{3}{2} \theta + \left( 929 - \frac{11800}{65-\theta} \right) - \frac{54000}{B_0 - B} \right]^2$$

where  $\frac{WV_L^2}{d^3}$  = Specific limit energy

W = Weight of projectile in pounds

$V_L$  = Limit velocity in feet per second

d = Diameter of projectile in inches

B = Brinell hardness of plate

t = Thickness of plate

$\theta$  = Angle of attack

$B_0 = 500 - 160 \log_{10} \frac{d}{d_2}$

$d_2 = 1.565$  inches (diameter of two pounder shot)

This formula agrees well with the 20 mm firing results.

**Shatter Gap**

In cases where the shatter velocity is higher than the ballistic limit for intact projectiles but lower than the ballistic limit for shattered projectiles, a shatter gap occurs (Figure 4). At low velocities the projectiles failed to perforate the plate and rebounded intact (Figure 4A). For velocities just above the ballistic limit for intact shot, the projectiles perforated intact (Figure 4B, 4C). At higher velocities the projectiles shattered and incomplete penetrations resulted (Figure 4D). As the velocity was increased further, the energy was sufficient to perforate the plate, even with shattered projectiles (Figure 4E).

**Comparison of AP and FAP Projectiles**

Comparison between the penetrations of AP and FAP projectiles should be made separately for conditions where the FAP remained intact during penetration and for conditions where they shattered.

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Against targets that FAP projectiles penetrated intact they were much superior to AP projectiles because the sharp "biting edge" of the FAP digs into the plate, thus reducing ricochet, and because the flat surface and sharp edge promote plate failure by an efficient plugging process. The superiority of the FAP, on an energy basis, ranges from 20 to 60 per cent, as is shown numerically in Table V, and graphically in Figures 5 and 6. The difference in extent of ricochet between the two types is illustrated in Figure 7, where the length of the FAP scoop is 2.0 inches as compared with 2.8 inches for the AP. For this plate condition, 3/8 inch at 60°, the FAP were 60 per cent more efficient than the AP, as is shown by the line shaded regions of Figures 5 and 6. The intact FAP were superior to the AP projectiles for all plate thicknesses up to 3/4 inch at 30° and 45° obliquities, for all plate thicknesses up to 5/8 inch at 55° and 60° obliquities, and for 3/8 inch plate at 70° obliquity. However, the FAP were barely able to defeat 5/8 inch plate at 0° obliquity without shattering. Only one complete penetration was obtained due to the extremely narrow velocity range in which complete penetration was possible with an intact FAP. Penetrations for this range are shown in Figure 8.

The possible existence of a shatter gap was not investigated for targets that were defeated by intact FAP projectiles. It is quite likely, however, that had the FAP been fired fast enough to shatter there would have been a range of velocities in which they would have failed to perforate and thus would have proved inferior to the AP projectiles. Against the heavier, more difficult targets the FAP projectiles shattered and were much inferior to the AP as indicated by the much greater specific limit energy required to defeat these targets (Figures 5 and 6).

The rupture limits\* for FAP projectiles are quite low (Figure 9), but in general increase with increasing obliquity. Figures 10 and 11, which represent firings against 7/8 inch plate at 30° and 45° obliquities, indicate that the transition from intact to shattered projectiles occurs over a narrow velocity band for a given plate condition. As stated before, the FAP shot were barely able to defeat 5/8 inch plate at 0° at 1090 fps without shattering (Figure 8). After shattering, the FAP were not able to defeat this target at velocities as high as 1600 f/s, even though they were able to defeat the same plate at 30° obliquity at 1455 f/s in an intact condition. This is considered rather unusual since the penetration ability of conventional AP shot decreases with increasing obliquity for the same plate thickness.

**Comparison of FAP and FAPT Projectiles**

Addition of a tip to flat nosed projectiles considerably raised the rupture velocity at normal and very low obliquities (Figure 9). At intermediate and high obliquities,

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\*Rupture limits are discussed more completely in a subsequent section.

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Table V. Summary of Finkford Arsenal 20 mm Firings

PLATE THICK	CAL IN.	A B C O			A B C O			A B C O			A B C O			A B C O			A B C O				
		A	B	C	O	A	B	C	O	A	B	C	O	A	B	C	O	A	B	C	O
1.43 - 1 / 8	3615 7.20 Sh -33.2 - FART (1854 * ) >3215 >5.09 Sh ... FAF (1680 * )	3320 5.11 Sh	3105 5.11 Sh	9.0		3660 7.04 Sh	3575 7.04 Sh	0.0		3435 6.21 Sh	2825 4.40 Sh	29.0		3480 6.38 Sh	3050 5.13 Sh	19.6		3670 7.20 Sh	3670 7.42 Sh	-3.1	- AP
1.27 - 1	2055 2.23 SI	2110 2.45 SI	10.0		2570 3.14 Sh	2125 2.49 Sh	28.1		3010 4.77 Sh	2535 3.44 Sh	517 28.0		3490 5.68 Sh	2940 5.05 Sh	-24.7		3480 6.38 Sh	3050 5.13 Sh	19.6	- FAPT	
1.11 + 7/8	3265* 5.25 Sh -155.4	285 2.77 Sh	1100 1.71 Sh		2425 3.10 Sh	2170 2.60 Sh	16.0		2955 4.50 Sh	2760 4.26 Sh?	7.0		3190 5.36 Sh	3065 5.18 Sh?	3.4		3670 7.20 Sh	3670 7.42 Sh	-3.1	- FAPT	
0.35 + 3/4	1790 1.77 Sh } 26.3	1650 1.54 Sh	21.6		2065 2.04 Sh	2065 2.04 Sh	36.2		3295* 5.18 Sh	3295* 5.18 Sh	-12.6		>3420 >5.05 Sh	-			>3465 >5.80	-		- FAP	
0.79 - 5/8	525 .22 SI	1680 1.43 Sh	2340 2.88 Sh		1980 2.18 Sh	1980 2.18 Sh	24.0		2490 3.27 Sh	2490 3.27 Sh	24.0		2785 4.09 Sh	2785 4.09 Sh			3330 5.74 Sh	3330 5.74 Sh	16.0	- AP	
0.54 - 1/2	1425 1.12 SI	8.0			1545 1.32 Sh	1.0			1795 1.50 Sh	1795 1.50 Sh	48.0		2300 2.91 Sh	2300 2.91 Sh	11.0		1615 1.15 Sh	1615 1.15 Sh	44.0	- AP	
0.48 - 3/8	1065 0.56 SI	54.0			1350* 0.90 Sh	1905 1.91 Sh			1995 2.03 Sh	1995 2.03 Sh	33.0		17760 4.01 Sh	17760 4.01 Sh			2280* 2.56 Sh	2280* 2.56 Sh	36.0	- 70°	

#### A: Protected ballast limits

### A: Protection of taste

$\delta$  = specific latent energy.

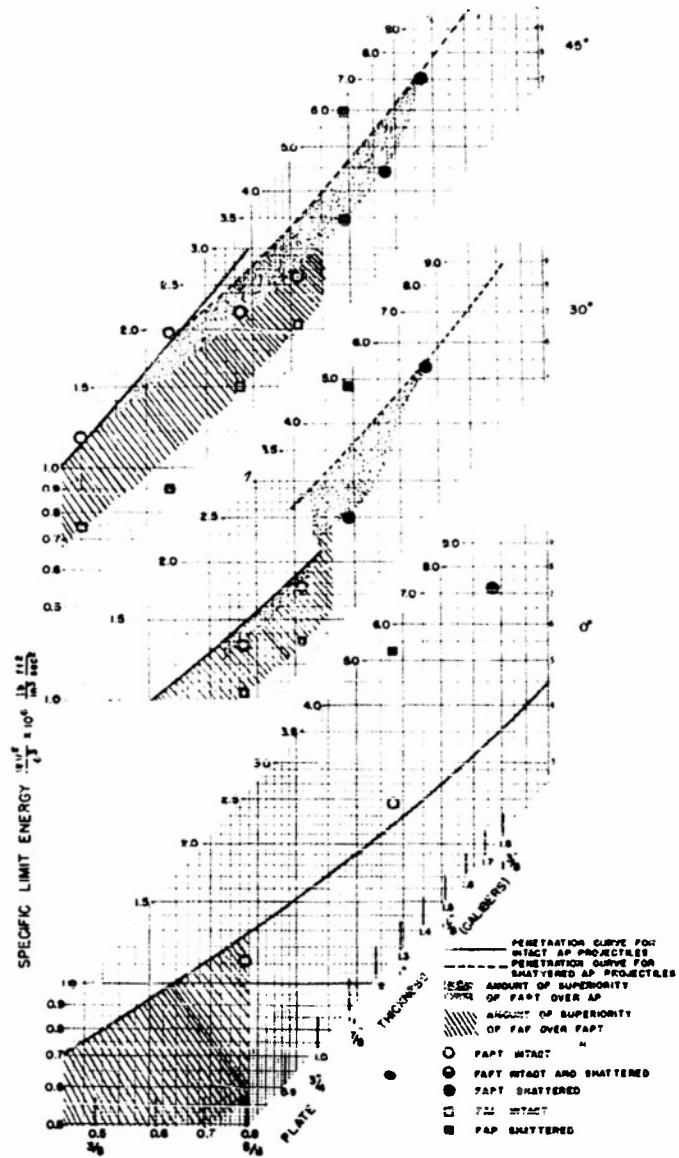
Project 1: Eighteen = Short Answer

**Approximate.**

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**Figure 5. Graph of specific limit energy vs plate thickness at  $0^\circ$ ,  $30^\circ$  and  $45^\circ$  obliquities for conventional ogival (AP), truncated ogival (FAP) and tipped truncated ogival (FAFT) 20 mm projectiles**

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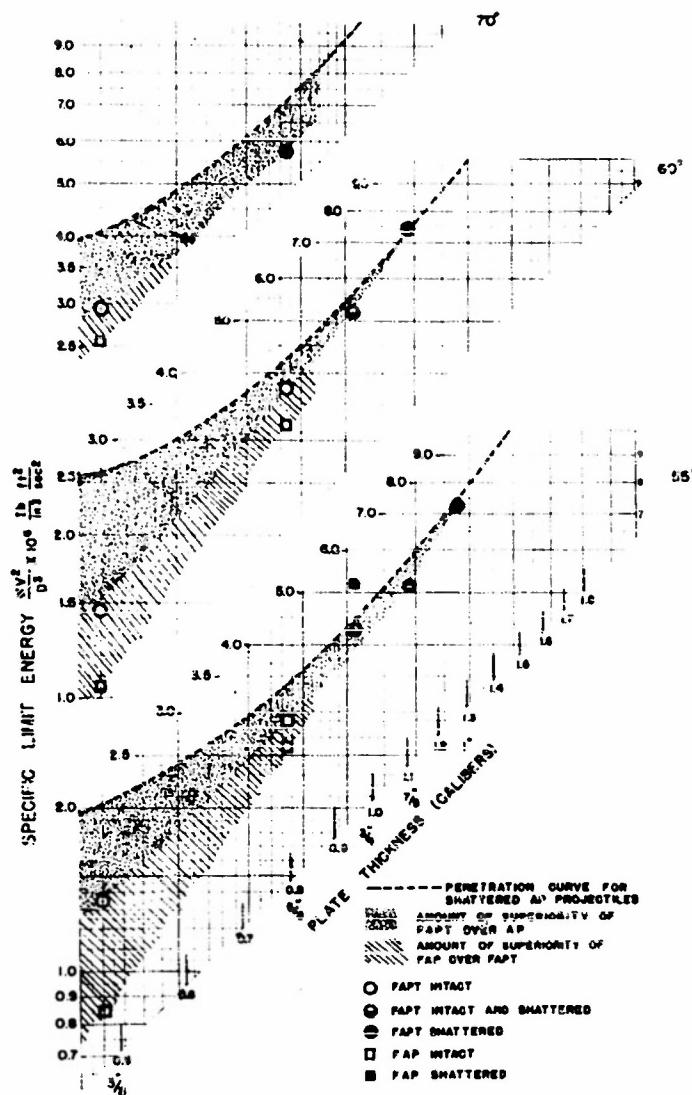


Figure 6. Graph of specific limit energy vs plate thickness at 55°, 60° and 70° obliquities for conventional ogival (AP), truncated ogival (FAP) and tipped truncated ogival (FAPT) 20 mm projectiles

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the increase in rupture velocity was not large. However, even at these angles, the tipped projectiles were effective at much higher velocities than were the untipped ones.

For conditions where both FAPT and FAP projectiles remained intact, the FAP projectiles were superior to FAPT projectiles, not only on an energy basis but also on a velocity basis, in spite of their lighter weight. This superiority is represented numerically in Table V and graphically by the line shaded areas of Figures 5 and 6.

Although the tip on the FAPT projectiles protects the biting edge of the projectile from shearing and protects the projectile body from rupturing at much higher velocities, the tip is not required as long as the FAP remains intact. Furthermore, it appears as if the tip reduces the effectiveness of the FAP when the body remains intact. Since the tip comprises 11 per cent of the total weight of the FAPT, its mass could be much more effective if it were part of the projectile body. In addition, the tip may get in the way of the body and interfere with the penetrative action of the biting edge. It may also cause the body to ricochet more than the FAP as indicated by the slightly longer scoops listed in the firing records of the Appendix. These reasons may account for the higher velocities and greater energies required of the FAPT to defeat the same targets as the intact FAP.

However, the FAPT were significantly superior to the FAP for target conditions for which the latter shattered, as can be noted in Figures 5 and 6 and Table V. A comparison of Figures 10 and 11 with Figure 12 provides an explanation of this superiority. At velocities slightly above the rupture velocity the untipped projectiles ruptured to a much greater extent than did the tipped projectiles, at least on the side of the projectile adjacent to the plate. For example, at 2553 fps (Figure 11A) the FAP were intact (the surface of the scoop is smooth) while only 18 fps faster, at 2571 fps (Figure 11B), they shattered completely. From Figure 12 the tipped projectiles fractured at 2690 fps while as much as 270 fps faster, at 2960 fps, the extent of smooth portion of the hole indicates that they did not shatter until they accomplished much of their penetration.

No shatter gaps were observed with FAPT projectiles for target conditions considered most likely to reveal such gaps.

**Comparison of AP and FAPT Projectiles**

The FAPT projectiles were equal or superior to the AP projectiles for almost all of the target conditions investigated (Table V and Figures 5 and 6). Exceptions to this were against heavy (thicker than one caliber) plate at 0° obliquity and against thin (one-half caliber) plate at intermediate (45°) obliquity. The FAPT were inferior to the AP against the thicker plate at 0° obliquity because they deformed more and,

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A-AP

S Sh at 2237 fps



B-FAP

SI at 1486 fps



C-FAPT

SI at 1632 fps **CONFIDENTIAL**

Figure 7. 3/8 H-13 at 60° comparison of complete penetrations at lowest velocities for different shot types

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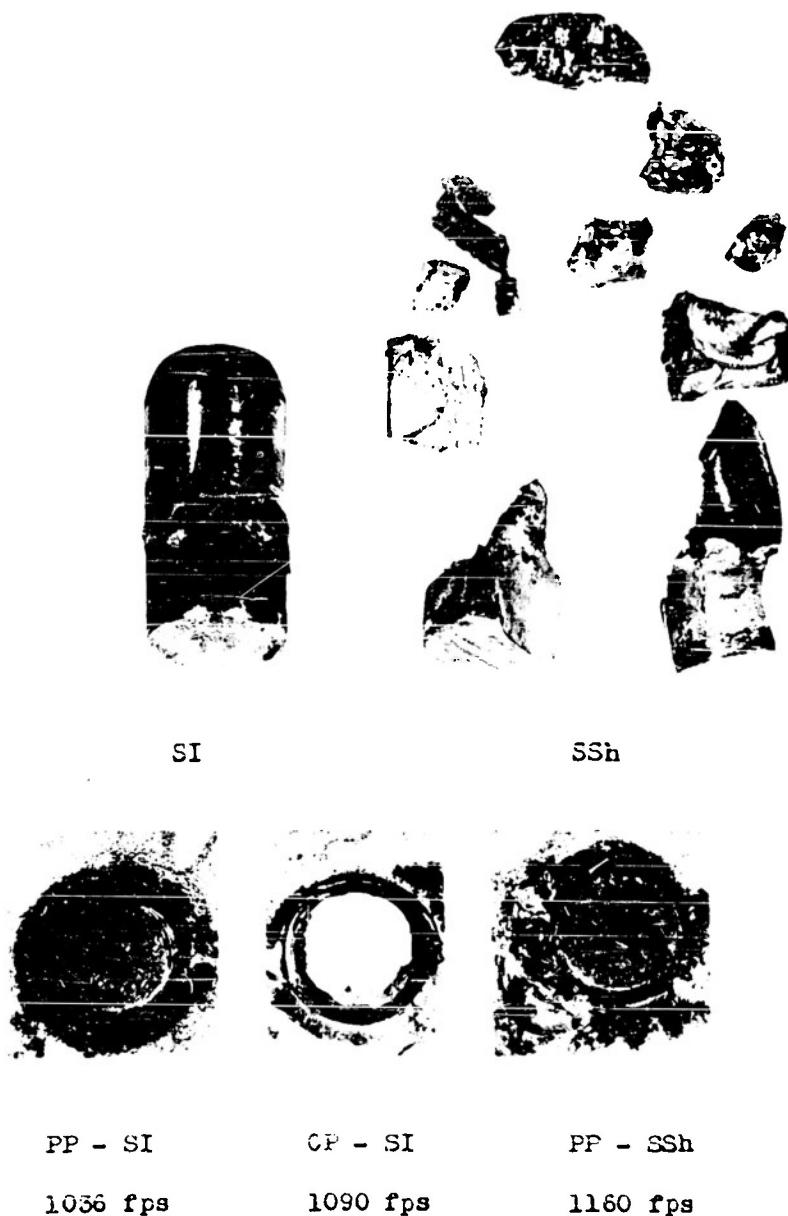
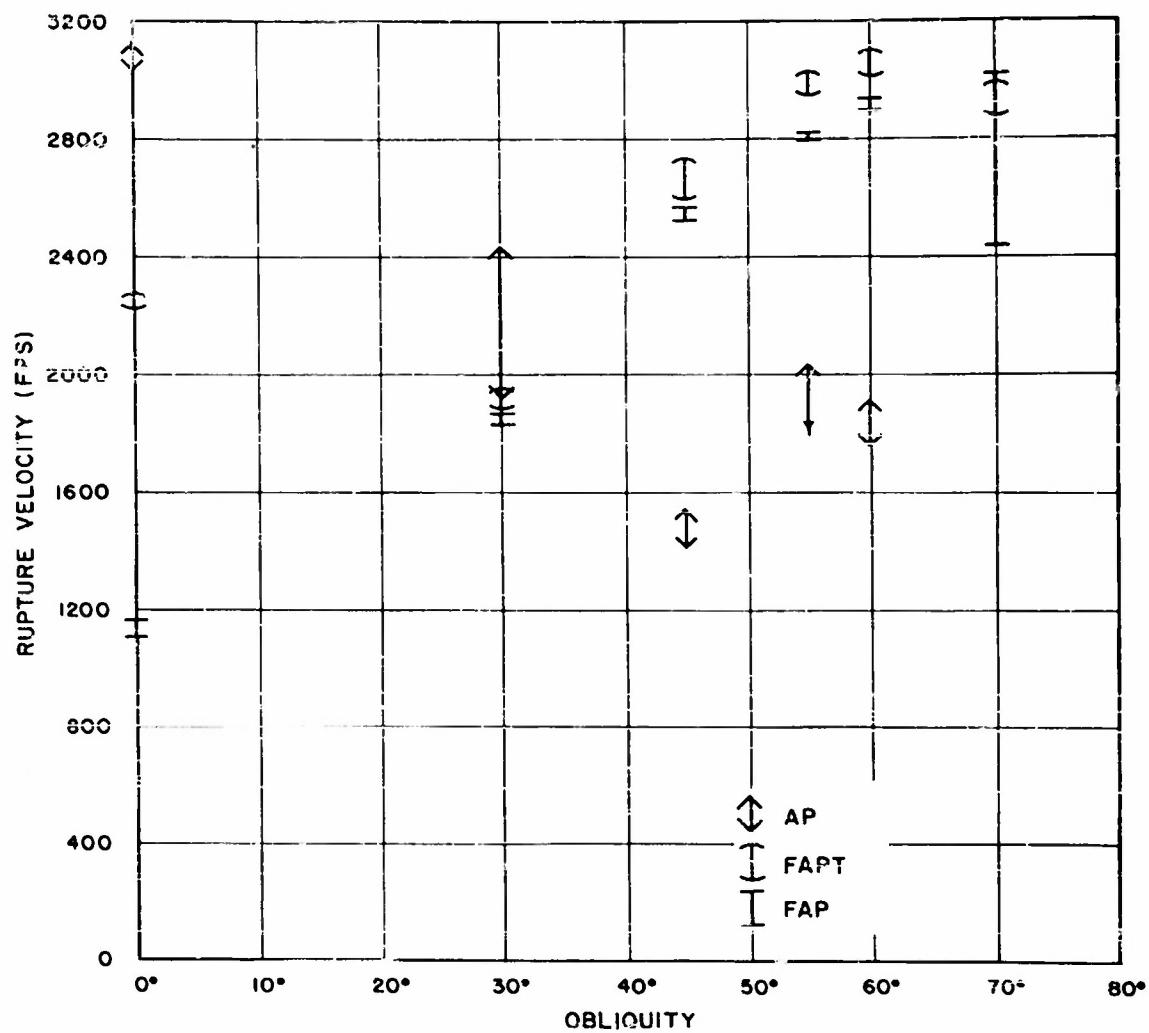


Figure 8. Penetration of 0.8 caliber plate by flat nosed projectiles

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**Figure 9. Rupture limits for AP, FAP and FAPT projectiles as a function of plate obliquity**

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therefore, required more energy for perforation than the AP. For thin plate at 45° obliquity the difference in ballistic limits between the two types was only 100 fps, which is not significant. Against the same 3/8 inch plate at high (55°, 60° and 70°) obliquities the FAPT were superior to the AP by as much as 44 per cent. This difference in penetration efficiency against relatively thin armor at high obliquity may be attributed to the difference in extent of projectile ricochet or scooping illustrated in Figure 7. Here, against 3/8 inch plate at 60° obliquity the length of FAPT scoop was about 2.5 inches as compared with 2.8 inches for the AP.

However, for most conditions of oblique attack the advantage of the FAPT type over the AP lies in its ability to remain intact at higher velocities without suffering excessive ricochet. The more efficient performance of the FAPT is illustrated in Figures 13 and 14. Figure 13 compares the performance of the two types fired at the same velocity against slightly overmatching (7/8 inch) plate at low (30°) obliquity. From the appearance of the scoop it can be seen that the FAPT projectiles were essentially intact during most of the penetration while the AP projectiles shattered early in the penetration process, even though the over-all extent of ricochet for both types is similar. The difference in the extent of damage produced by the two types of projectiles is emphasized by the appearance of the back of the plate (Figure 13). The FAPT punched a hole through the plate but the AP produced only a small bulge on the back surface. Firings against undermatching (5/8 inch) plate at high (60°) obliquity are compared in Figure 14. Against this target the AP projectiles remained intact during part of the penetration while FAP and FAPT projectiles remained intact throughout. Figure 15 compares the performance of the AP and FAPT at similar velocities against slightly overmatching (7/8 inch) plate at high (55°) obliquity. Although both types shattered, the FAPT remained intact longer in the penetration process as indicated by the longer, smoother scoop. As a result, the ballistic limit obtained with the FAPT was 430 fps lower than that obtained with the AP. Figure 16 shows the highest partial and lowest complete penetrations obtained with both projectile types for the same target as Figure 15.

**Comparison of AP, FAP and FAPT Projectiles**

Three factors which influence projectile penetrating ability are: resistance to rupture, resistance to ricochet or turning, and type of plate failure which they induce.

Rupture and Ricochet. Resistance to rupture of a projectile is highly dependent upon the angle of attack (Figure 9). Rupture limits for AP, FAP, and FAPT projectiles are plotted as a function of obliquity. All plate thicknesses were included without regard for possible variations in rupture due to differences in plate thickness. The penetration efficiency does not correlate with this graph. Since only the projectile recoveries were used to determine rupture, the stage of penetration at which projectile

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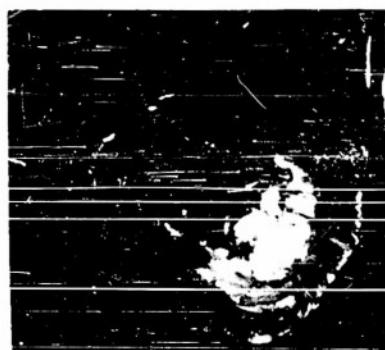
A

SI at 1835 fps



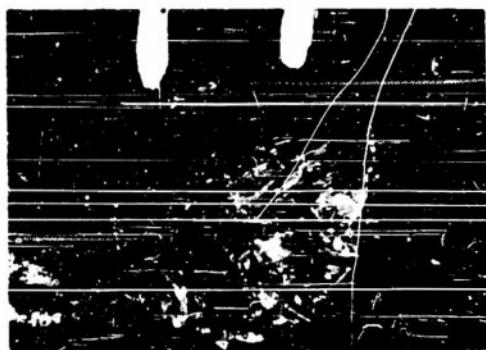
B

S Fr at 1865 fps



C

S Sh at 1980 fps



D

S Sh at 2116 fps

Figure 10. FAP vs 7/8 H-48 at 30° showing evidence of shot break-up with increasing velocity

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A

SI at 2553 fps



B

S Sh at 2571 fps

Figure 11. EAP vs 7/8 H-47 at 45° showing evidence of shot breakup with increasing velocity

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A

SI at 2600 fps



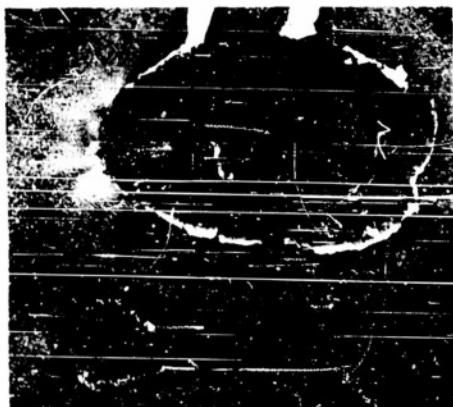
B

S Fr at 2690 fps



C

S Sh at 2780 fps



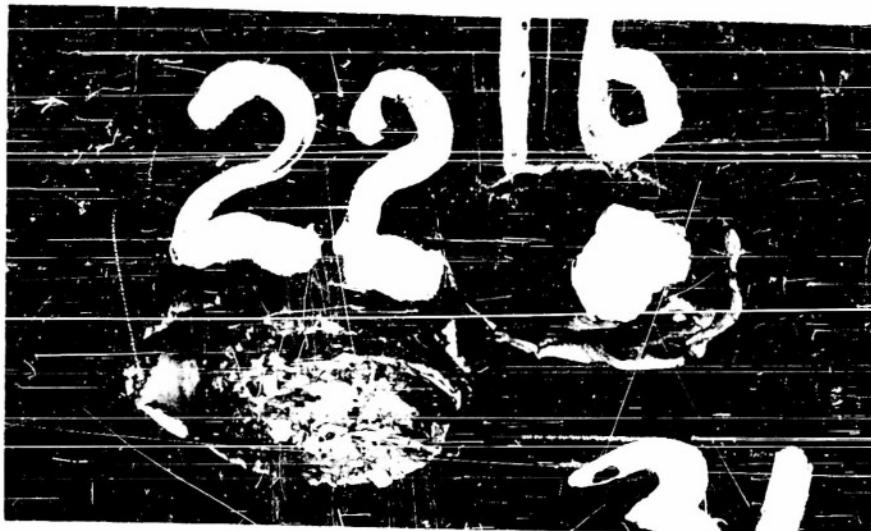
D

S Sh at 2960 fps

Figure 12. FAPT vs 7/8 H-47 at 45° showing little effect on penetration with increasing shot velocity and breakup

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FRONT

A-AP

B-FAPT

PP at 2121 fps

CP at 2153 fps



BACK

C-FAPT

D-AP

Figure 13. Comparative performance of AP and FAPT shattered shot vs 7/8 H-48 at 30° at similar velocities

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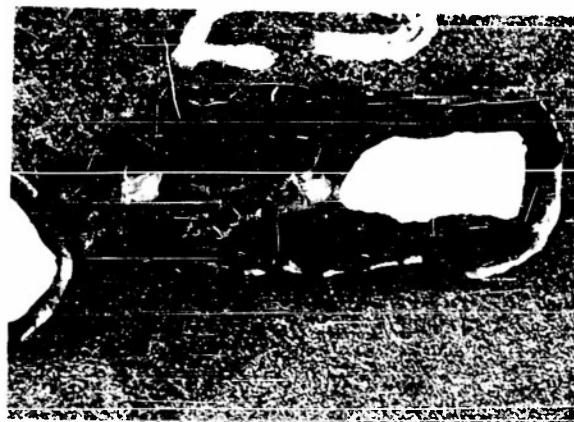
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A-AP

PP at 2640 fps-S Sh



B-FAP

CP at 2615 fps-SI



C-FAPT

CP at 2617 fps-SI

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Figure 14. Comparison of penetration performance of AP, FAP and FAPT shot vs 5/8 H-21 at 60° fired at similar velocities

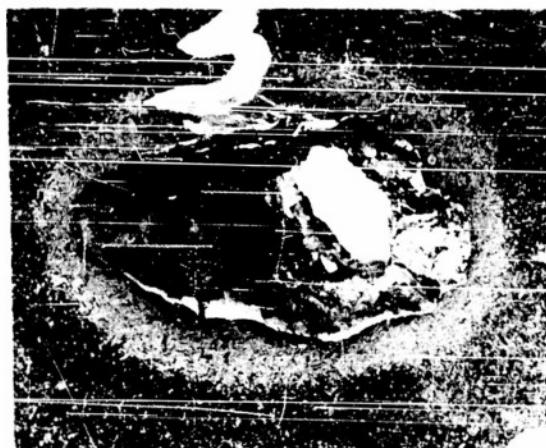
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A-AP

PP at 3130 fps-S Sh



B-FAPT

CP at 3120 fps-S Sh

Figure 15. Comparative performance of AP and FAPT shot vs 7/8 H-47 at 55° at similar velocities

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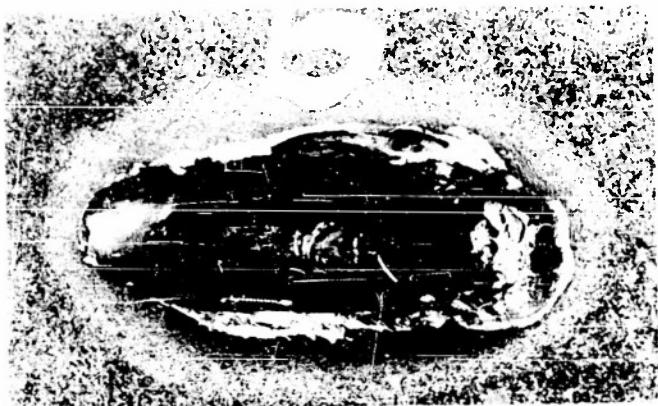
A-AP

PP at 3442 fps-S Sh



R-AP

CP at 3498 fps-S Sh



C-FAPT

PP at 3029 fps-S Sh



D-FAPT

CP at 3120 fps-S Sh

Figure 16. Comparison of highest partial and lowest complete penetrations for AP and FAPT shot vs 7/8 H-47 at 55°

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failure occurred is not indicated. From Figure 9 it may be noted that for obliquities below 30° the AP were most resistant to rupture, the FAPT were intermediate and the FAP were least resistant. At obliquities above 30° the FAPT were most resistant to rupture, the FAP were intermediate and the AP were least resistant to rupture. At all angles, except 0°, and for intact projectiles, the FAP ricocheted least, the FAPT were intermediate and the AP ricocheted most. If an AP projectile ruptures, there is less likelihood of ricochet. For example, at 55° obliquity and at velocities of about 1800 to 2800 fps the FAP and FAPT remained intact and ricocheted, whereas the AP ruptured and had the least tendency to scoop. However, at velocities below 1800 fps, where the AP remained intact, they made the longest scoops.

Plate Failure. The manner\* in which a plate fails depends upon many factors, such as the physical and metallurgical qualities of the plate, the angle of impact, the geometry and caliber of projectile, and deformation of the projectile. For most of the conditions in this investigation, plates failed by some type of plug formation. Exceptions were at low angles where the penetration with AP and FAPT projectiles was ductile and against 1 1/8 and 1 3/8 inch plate which failed by the ejection of spalls because of inferior plate quality. An interesting target condition, for which a different type of plate failure was obtained with each projectile type, was 5/8 inch at 0° obliquity. Figure 17 shows that, for this target, the AP caused a ductile failure with formation of petals, the FAP caused plate failure by plugging, and the FAPT induced a failure that showed a tendency for spall formation. The petals dislodged by the AP have a wiped or sheared appearance, whereas those dislodged by the FAPT have a granular or fractured appearance over a large area.

Over-all Ballistic Comparison. As stated previously, the ballistic limits and corresponding specific limit energies obtained with the AP, FAP, and FAPT types for each target condition are summarized in Table V and plotted in Figures 5, 6, 18, and 19. Figures 5 and 6 compare the energies necessary to defeat the various targets as a function of plate thickness for different angles of attack, whereas Figures 18 and 19 compare these energies as a function of obliquity for different plate thicknesses. The line shaded areas of Figure 5 show the regions of superiority of the intact FAP projectiles over both the FAPT and AP types for plate at 0°, 30° and 45° obliquities. Although the FAP were superior against one caliber plate at 45° obliquity, they were scarcely able to defeat 0.8 caliber plate at 0° obliquity. Against heavier targets the FAP shattered and were much inferior to the AP and the FAPT. As shown by the stippled region, the FAPT projectiles were generally superior to the AP, even though the FAPT shattered against the heavier targets. The line shaded regions of Figure 6 show the FAP to be superior to the AP and FAPT at 55°, 60°, and 70° obliquities as long as they remained intact. Upon shatter the FAP were much inferior. In the stippled regions of

\*A more complete explanation of various types of plate failure is given in Frankford Arsenal, Pitman-Dunn Laboratories Report R-902, by R. B. Sawyer, February 1951.

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the graph the FAPT were superior to the AP up to and including 1.1 caliber armor at 55° and 0.8 caliber armor at 70° obliquity. For the thicker targets the AP and FAPT types appeared to be equal in performance.

Figure 20 summarizes these firings qualitatively in the form of a block diagram. For a certain range of plate thicknesses the FAP type was superior to both the other types for all obliquities from 0° to 70°. Similarly, for a range of greater plate thicknesses, the FAPT type was superior. The AP type was best in the limited region of very heavy plate at very low obliquity and was equivalent to the FAPT for the heaviest plates tested at the high obliquities. If the hardness and ductility of these three types were either raised or lowered, some of the ballistic limits and the boundaries of the zones probably would be different. The performance of the FAP and FAPT types is expected to be affected more significantly by such changes than that of the AP.

Figures 18 and 19 show that the specific limit energy increases linearly, to a first approximation, as the secant of the angle of attack is raised for all plate thicknesses.

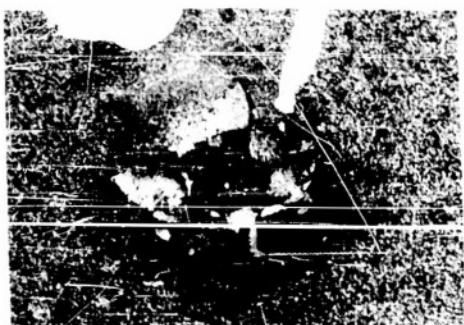
**Full Caliber Projectile Firings**

Some of these 20 mm penetration results have been confirmed by limited firings of truncated 75 mm AP M338 (T148) shot, truncated conical 120 mm AP T116E2 shot and tipped truncated 76 mm AP T166 shot. In addition, preliminary results have been obtained by the US Naval Proving Ground in a program sponsored by the Army Ordnance Department to provide a systematic comparison of the regions of superiority of the AP, FAP and FAPT types with three-inch shot homologous to the 20 mm models. There is reason to believe that large caliber shot of these unconventional types can be made to perform as efficiently as the 20 mm models.

**CONCLUSIONS**

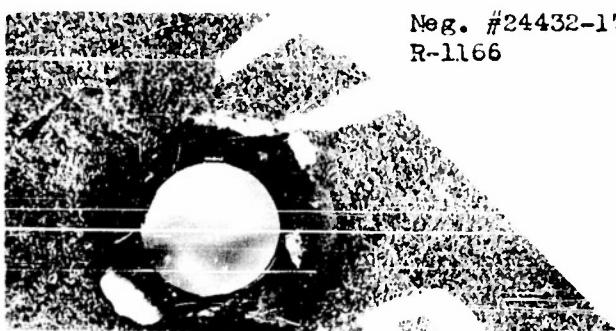
1. No one of the AP, FAP and FAPT projectile designs is consistently superior for the attack of all types of armor targets.
2. The FAPT type is generally equivalent or superior to the AP, even though both types shatter against the heavier targets.
3. For conditions where FAP projectiles remain essentially intact during penetration, they are superior to the AP and FAPT types. At somewhat higher striking velocities and for targets that FAP projectiles cannot defeat intact, they are much inferior to the AP and FAPT.

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A-AP

PP at 1515 fps-SI



B-AP

CP at 1533 fps-SI



C-FAP

PP at 1036 fps-SI



D-FAP

CP at 1090 fps-SI



E-FAPT

PP at 1425 fps-SI



F-FAPT

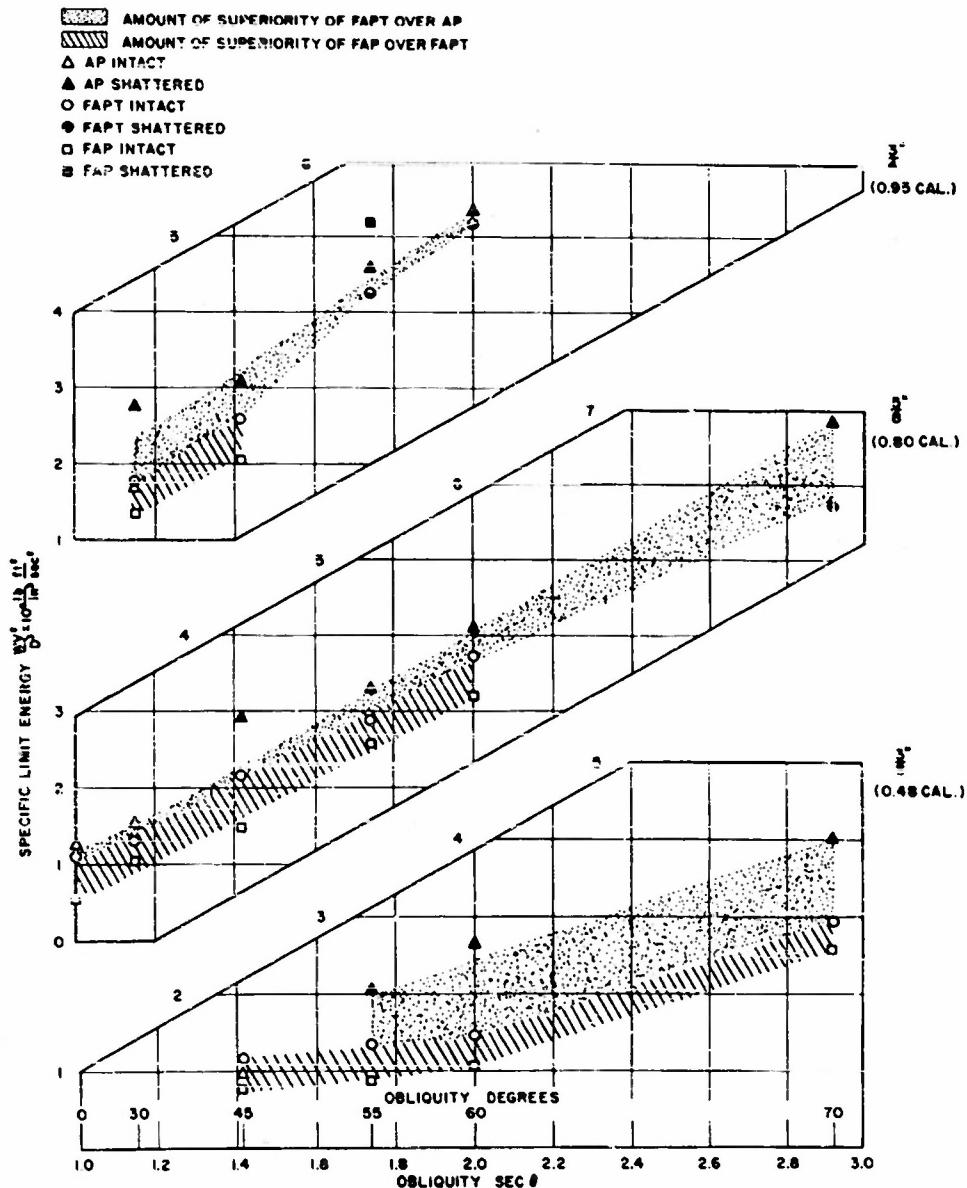
CP at 1430 fps-SI

Figure 17. Comparison of plate failure for 5/8 H-29 at 0° obliquity vs AP, FAP and FAPT intact shot

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**Figure 18. Graph of specific limit energy vs obliquity for 3/8", 5/8" and 3/4" plate thicknesses for conventional ogival (AP), truncated ogival (FAP) and tipped truncated ogival (FAPT) 20 mm projectiles**

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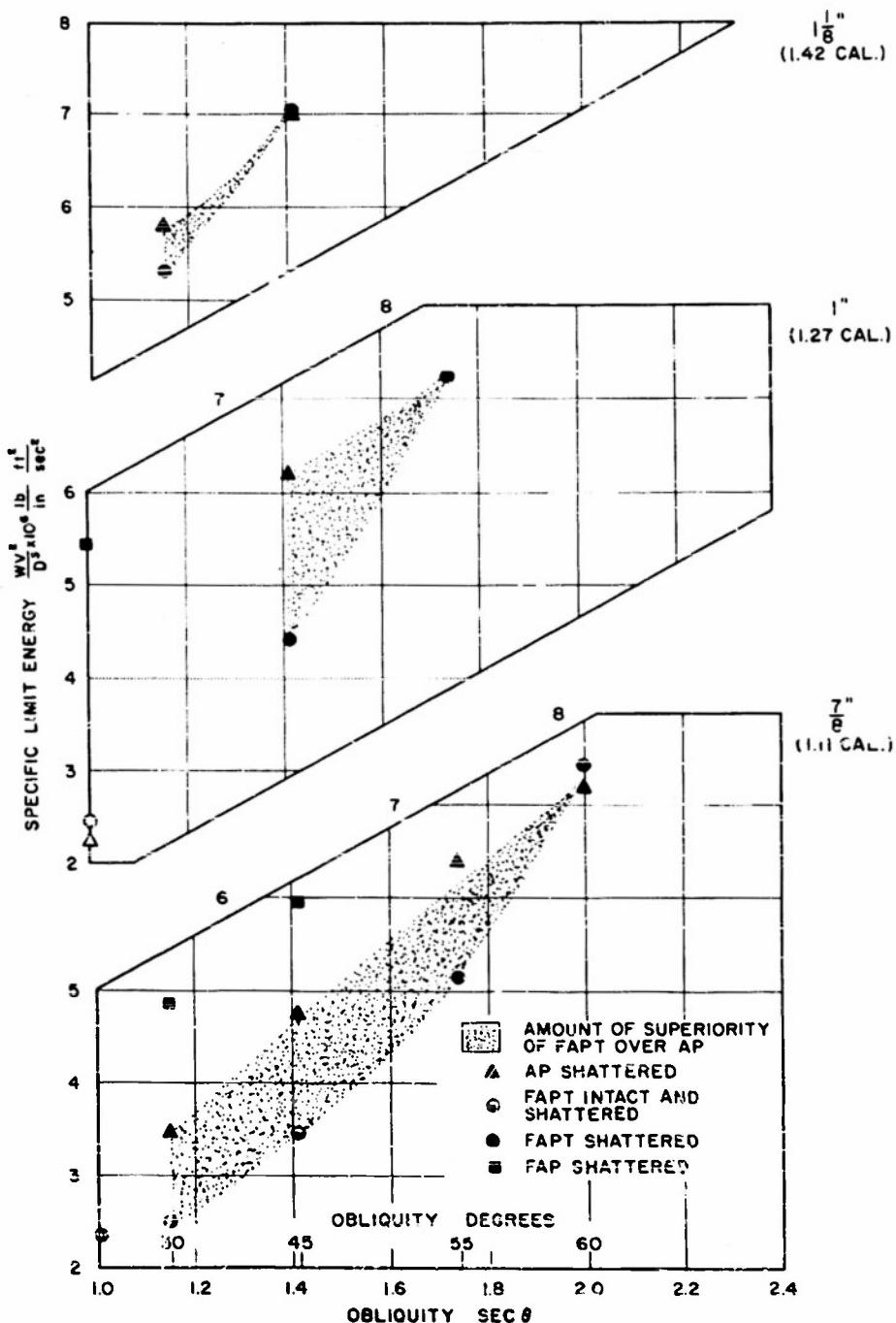


Figure 19. Graph of specific limit energy vs obliquity for  $\frac{7}{8}$ ", 1" and  $1\frac{1}{8}$ " plate thicknesses for conventional ogival (AP), truncated ogival (FAP) and tipped truncated ogival (FAPT) 20 mm projectiles

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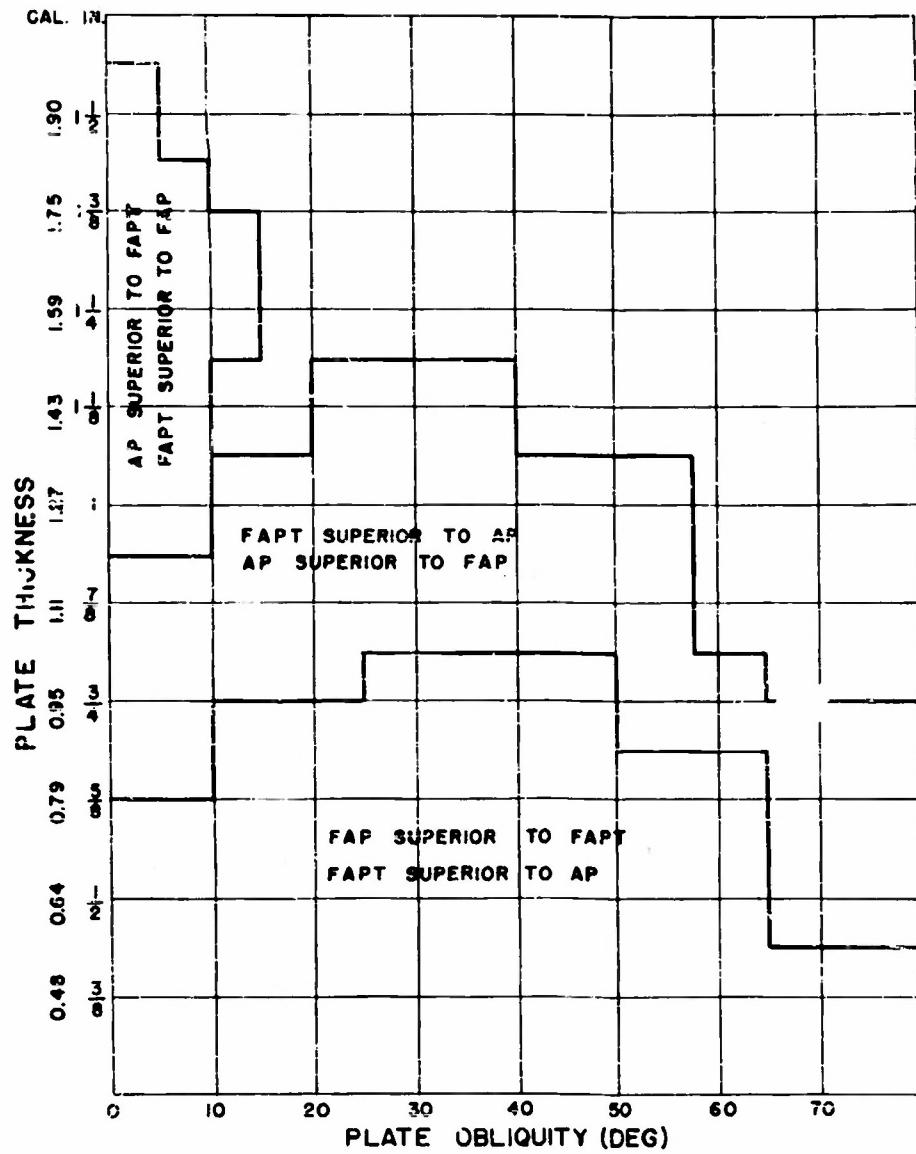


Figure 20. Regions of superiority for conventional ogival (AP), truncated ogival (FAP), and tipped truncated ogival (FAPT) 20 mm projectiles

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4. Conventional AP projectiles are best in the limited region of very heavy plate at very low obliquity and are equivalent to the FAPT for the heaviest plates at the high obliquities.

5. Previous limited firings indicate that full caliber projectiles of these types can be made to show the same relative penetration performance as the 20 mm models if adequate projectile hardness and ductility are provided.

#### **RECOMMENDATIONS**

The foregoing results have shown the usefulness of each one of the projectile designs for defeat of certain steel armor targets. It is recommended that the truncated designs also be considered for other missiles, such as shell, rockets, and bombs, which may be made of steel or other materials. Furthermore, it is believed that the truncated types should be investigated for defeat of light alloy aircraft armor at very high obliquities.

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**APPENDIX**

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**ABBREVIATIONS DESCRIBING PENETRATION RESULTS**

PP	- Partial penetration
CP(A)	- Complete penetration - Army criterion*
CP(P)	- Complete penetration - Protection criterion*
CP(NF)	- Complete penetration - Navy criterion, shot fractured†
CP(NS)	- Complete penetration - Navy criterion, shot shattered†
NB	- No bulge
VSB	- Very small bulge
SB	- Small bulge
MB	- Medium bulge
LB	- Large bulge
VLB	- Very large bulge
Ck	- Cracks
PO	- Plug out
PH	- Plug hanging
PS	- Plug started
BP	- Back petals
BPO	- Back petals off
BPS	- Back petals started
BS	- Back spall
BSS	- Back spall started
BSH	- Back spall hanging
BSO	- Back spall out
FP	- Front petals
FPO	- Front petals off
FSO	- Front spall out
NI**	- Nose intact
BI***	- Base intact
SI	- Shot intact
Sh	- Shatter
Fr	- Fracture
LS	- Local shear
SNR	- Shot not recovered
PBL	- Protection ballistic limit

\*Defined according to Ordnance Department Bulletin No. 24-44.

\*\*Fractions following NI indicate approximate ratio of nose fragment to total shot body.

\*\*\*Fractions following BI indicate approximate ratio of base fragment to total shot body.

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**FIRING RECORD**

**I. Firing against 3/8 Inch Homogeneous Armor**

**A. Firing vs Plate No. 14 (302 to 321 Bhn) at 45° Obliquity**

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop**</u>
<u>AP T33 - Lot 2160</u>			
1703	CP(NF)-PO	BI 1/2-LS	(1.5 x 0.9)
1567	CP(A&P)-PO	BI 1/2-Sh-LS-Fr	(1.2 x 0.8)
1431	CP(NI)-PO	SI	(1.8 x 0.9)
1360*	CP(A&P)-PO	SI	(2.1 x 0.9)
1331*	PP-MB	SI	(2.2 x 0.8)
1310	CP(A)-PS	SI	(1.8 x 0.9)

PBL = 1345

<u>FAP T33 - Lot 2160F</u>			
1309	CP(A&P)-PO	SI	(1.5 x 0.9)
1255*	CP(A&P)-PO	SI	(1.4 x 0.9)
1196*	CP(A)-PH	SI	(1.3 x 0.8)
1100	CP(A)-PS	SI	(1.0 x 0.9)

PBL = 1225

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.  
\*\*Scoop extent in inches.

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I. Firing against 3/8 Inch Homogeneous Armor (Cont'd)

A. Firing vs Plate No. 14 (302 to 321 Bhn) at 45° Obliquity (Cont'd)

<u>Striking Velocity (ips)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>FAPT T33</u>			
1550	CP(A&P)-PO	SI	(2.0 x 0.9)
1534 <sup>+</sup>	CP(A&P)-PO	SI	(1.6 x 0.9)
1517 <sup>+</sup>	CP(A)-Ck	SI	(1.8 x 0.9)
1486	CP(A&P)-PO	SI	(2.4 x 0.8)
1473 <sup>**</sup>	CP(A&P)-PO	SI	(1.9 x 0.9)
1435 <sup>**</sup>	PP-LB-Ck	SI	(1.7 x 0.9)
1421	PP-MB	SI	(2.2 x 0.9)
1409 <sup>+</sup>	CP(A&P)-P	SI	(2.1 x 0.8)
1378 <sup>+</sup>	PP-MB	SI	(2.1 x 0.8)
1287 <sup>+</sup>	PP-SB	SI	(1.7 x 0.9)

PBL = 1455

B. Firing vs Plate No. 13 (302 to 321 Bhn) at 55° Obliquity

		<u>AP T33</u>	
2042	CP(NI)-PO	SI	(2.4 x 0.9)
1978*	CP(A&P)-PO	Sh-Fr-LS	(1.9 x 0.9)
1950*	CP(A)-PS	NI 1/3-Sh-Fr-LS	(2.9 x 0.9)
1858	CP(A)-Ck	BI 3/5-NI 1/5-Sh-Fr-LS	(3.0 x 0.9)

PBL = 1965

\*Firing vs Plate No. 13 (302 to 321 Bhn).

\*\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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I. Firing against 3/8 Inch Homogeneous Armor (Cont'd)

B. Firing vs Plate No. 13 (302 to 321 Bm) at 55° Obliquity (Cont'd)

Striking Velocity (fps)	Plate	Results Projectile	Scoop
<u>FAP</u>			
1388	CP(A&P)-PO	SI	(1.7 x 0.9)
1365	CP(A&P)-PO	SI	(1.6 x 0.9)
1330*	CP(A&P)-PO	SI	(1.6 x 0.9)
1300*	PP-MB	SI	(1.8 x 0.8)
1230	PP-MB	SI	(1.8 x 0.9)
PBL = 1315			
<u>FAPT</u>			
1617	CP(A&P)-PO	SI	(2.0 x 0.9)
1581*	CP(A&P)-PO	SI	(2.0 x 0.9)
1548*	PP-PS	SI	(1.9 x 0.8)
1520	PP-LB	SI	(2.0 x 0.8)
PBL = 1565			

C. Firing vs Plate No. 13 (302 to 321 Bm) at 60° Obliquity

		<u>AP</u>	
2306	CP(A&P)-PO	BI 1/3-Sh-Fr-LS	(2.9 x 0.9)
2237*(Fig 7)	CP(A&P)-PO	BI 1/3-Sh-Fr-LS	(2.7 x 0.8)
2200*	CP(A)-PH	BI 1/2-Sh-Fr-LS	(2.9 x 0.8)
2077	PP-LB-Ck	Sh-Fr-LS	(2.9 x 0.8)
1808	PP-MB	BI 3/5-NI 2/5-Fr	(2.9 x 0.8)
PBL = 2220			

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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## I. Firing against 3/8 Inch Homogeneous Armor (Cont'd)

## C. Firing vs Plate No. 13 (302 to 321 Ehm) at 60° Obliquity (Cont'd)

<u>Striking Velocity (ips)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>FAP</u>			
1610	CP(AP)-PO	SI	(2.0 x 0.9)
1486*(Fig 7)	CP(AP)-PO	SI	(1.9 x 0.9)
1436*	PP-LB	SI	(2.0 x 0.9)
1370	CP(A)-PS	SI	(1.7 x 0.9)
1300	PP-SB	SI	(2.1 x 0.8)
PBL = 1460			

		<u>FAPT</u>	
2194	CP(NF)-PO	Fr	(2.2 x 0.9)
1897	CP(AP)-PO	Fr	(2.5 x 0.9)
1666	CP(AP)-PO	SI	(2.5 x 0.8)
1632*(Fig 7)	CP(AP)-PO	SI	(2.0 x 0.5)
1600*	PP-LB	SI	(2.5 x 0.8)
1497	PP-MB	SI	(2.4 x 0.9)
PBL = 1615			

## D. Firing vs Plate No. 14 (302 to 321 Ehm) at 70° Obliquity

		<u>AP</u>	
2861	CP(AP)-PO	SI 1/4-Sh-Fr-LS	(3.4 x 0.9)
2817	CP(AP)-PO	Sh-Fr-LS	(2.7 x 0.7)
2760*	CP(AP)-PO	Sh-Fr-S	(3.5 x 0.9)
2760*	CP(A)-PS	Sh-Fr-LS	(3.5 x 0.8)
PBL = 2760			

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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## I. Firing against 3/8 Inch Homogeneous Armor (Cont'd)

## D. Firing vs Plate No. 14 (302 to 321 Bm) at 7° Obliquity (Cont'd)

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>FAP</u>			
2437	CP(A&P)-PO	SI	(3.5 x 0.9)
2386	CP(A&P)-PO	SI	(3.5 x 0.9)
2348 <sup>++</sup>	CP(A&P)-PO	SI	(3.5 x 0.9)
2269 <sup>++</sup>	CP(A)-PH	SI	(3.7 x 0.9)
2274 <sup>++</sup>	CP(A&P)-PO	SI	(3.4 x 0.9)
2215 <sup>++</sup>	CP(A)-PH	SI	(3.7 x 0.9)
2130	PP-SB	SI	(3.4 x 0.8)

PBL = 2280

		<u>FAPT</u>	
2685	CP(A&P)-PO	SI	(3.9 x 0.9)
2355	CP(A&P)-PO	SI	(3.8 x 0.9)
2339*	CP(A&P)-PO	SI	(3.5 x 0.9)
2277*	PP-LB-PS	SI	(3.8 x 0.9)
2190	PP-LB-Ck	SI	(3.8 x 0.9)

PBL = 2305

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

\*\*Velocities averaged to determine protection ballistic limit and specific limit energy.

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**II. Firing against 1/2 Inch Homogeneous Armor**

**Firing vs Plate No. 23 (302 to 311 Bhr.) at 45° Obliquity**

<i>Striking Velocity (fps)</i>	<i>Plate</i>	<i>Results Projectile</i>	<i>Scoop</i>
<u>AP</u>			
1985	CP(A&P)-PO	Sh-Fr-LS	(1.3 x 0.9)
1936*	CP(A&P)-PO	Sh-Fr-LS	(1.3 x 1.0)
1876*	PP-MB	Sh-Fr-LS	(1.2 x 0.9)
1705	PP-MB	BI 3/5-NI 2/5-Fr	(2.8 x 1.0)
PBL = 1905			

		<u>FAP</u>	
1584	CP(A&P)-PO	SNR	(1.5 x 1.0)
1497	CP(A&P)-PO	SI	(1.5 x 1.0)
1435	CP(A&P)-PO	SI	(1.4 x 0.9)
1408 <sup>++</sup>	CP(A&P)-PO	SI	(1.4 x 0.9)
1361 <sup>++</sup>	PP-MB	SI	(1.4 x 0.9)
1334 <sup>++</sup>	CP(A&P)-PO	SI	(1.4 x 0.9)
1274 <sup>++</sup>	PP-LB	SI	(1.4 x 0.9)
1254	PP-MB	SI	(1.3 x 0.9)
1170	PP-SB	SI	(1.2 x 0.8)

PBL <sup>a</sup> = 1350

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

<sup>++</sup>Velocities averaged to determine the protection ballistic limit and specific limit energy.

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**II. Firing against 1/2 Inch Homogeneous Armor (Cont'd)**

**Firing vs Plate No. 23 (302 to 311 Bhn) at 45° Obliquity (Cont'd)**

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>FAPT</u>			
1962	CP(A&P)-PO	SI	(2.2 x 0.9)
1960	CP(A&P)-PO	SI	(1.8 x 0.9)
1910*	CP(A&P)-PO	SI	(1.9 x 0.9)
1869*	CP(A)-PS	SI-Slight Fr	(2.2 x 0.9)
1716	PP-LB-Ck	SI	(1.8 x 0.9)
PBL = 1890			

**III. Firing against 5/8 Inch Homogeneous Armor**

**A. Firing vs Plate No. 29 (311 Bhn) at 0° Obliquity**

	<u>AP</u>	
1558	CP(NI)-BPO	SI
1533*(Fig 17)	CP(NI)-BP	SI
1515*(Fig 17)	CP(A)-EPS	SI
1490	CP(A)-EPS	SI
1426	CP(A)-EPS	SI

PBL = 1525

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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**III. Firing against 5/8 Inch Homogeneous Armor (Cont'd)**

**A. Firing vs Plate No. 29 (311 Bhn) at 0° Obliquity (Cont'd)**

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>
<u>FAP</u>		
1603	PP-SB	Sh-Fr-LS
1410	PP-SB	Sh-Fr-LS
1160 (Fig 8)	PP-SB	Sh-Fr-LS
1090*(Fig 8,17)	CP(A&P)-PO	SI
1040*	PP-MB-Cl	SI
1036 (Fig 8,17)	PP-MB-PS	SI
1025	PP-SB	Sh-Fr-LS

PBL = 1055

<u>FAP I</u>		
1460	CP(A&P)-BP	SI
1430*(Fig 17)	CP(NI)-BP	SI
1425*(Fig 17)	CP(A)-BPS	SI
1382	CP(A)-BPS	SI
1347	CP(A)-BPS	SI

PBL = 1425

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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**III. Firing against 5/8 Inch Homogeneous Armor (Cont'd)**

**B. Firing vs Plate No. 29 (311 Bhn) at 30° Obliquity**

<i>Striking Velocity (fps)</i>	<i>Plate</i>	<i>Results Projectile</i>	<i>Scoop</i>
<u>AP</u>			
1752	CP(NI)-PO	SI	(1.4 x 1.0)
1700*	CP(NI)-PO	SI	(1.4 x 0.9)
1660*	CP(A)-PS	SI	(1.5 x 1.0)
1657	CP(A)-PS	SI	(1.4 x 1.1)
1617	CP(A)-PS	SI	(1.6 x 1.1)
1580	CP(A)-PS	SI	(1.5 x 1.0)

$\bar{PEL} = 1680$

		<u>FAP</u>	
1660	CP(A&P)-PO	SI	(1.3 x 1.1)
1600	CP(A&P)-PO	SI	(1.3 x 1.0)
1575	PP-PS	BI 3/4-Sh-LS	(1.0 x 1.0)
1525	CP(A&P)-PO	SI	(1.2 x 1.0)
1470*	CP(A&P)-PO	SI	(1.2 x 1.1)
1443*	CP(A)-PS	SI	(1.2 x 1.0)
1395	CP(A)-PS	SI	(1.2 x 1.0)

$\bar{PEL} = 1455$

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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**III. Firing against 5/8 Inch Homogeneous Armor (Cont'd)**

**B. Firing vs Plate No. 29 (311 Bhn) at 30° Obliquity (Cont'd)**

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>FAPT</u>			
1658	CP(A&P)-PO	SI	(1.4 x 1.0)
1587	CP(A&P)-PO	SI	(1.7 x 1.0)
1570*	CP(A&P)-PO	SI	(1.7 x 1.0)
1524*	PP-PS	BI 1/2	(1.6 x 1.0)
1512	PP-PS	BI 1/2-NI 1/2-Fr	(1.6 x 1.0)
1455	PP-MB-Ck	SI	(1.6 x 1.0)

PBL = 1545

**C. Firing vs Plate No. 29 (311 Bhn) at 45° Obliquity**

		<u>AP</u>	
2425	CP(A&P)-PO	Sh-Fr-LS	(1.5 x 1.1)
2392	CP(A&P)-PO	BI 1/3-Sh-Fr-LS	(1.5 x 1.1)
2372	CP(A&P)-PO	Sh-Fr-LS	(1.4 x 1.1)
2343*	CP(A&P)-PO	BI 1/3-Sh-Fr-LS	(1.4 x 1.1)
2305*	PP-LB-Ck	Sh-Fr-LS	(1.4 x 1.0)
2200	PP-LB-Ck	Sh-Fr-LS	(1.3 x 1.0)

PBL - 2340

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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**III. Firing against 5/8 Inch Homogeneous Armor (Cont'd)**

**C. Firing vs Plate No. 29 (311 Bhn) at 45° Obliquity (Cont'd)**

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>FAP</u>			
2060	CP(A&P)-PO	SI	(1.9 x 1.1)
1825	CP(A&P)-PO	SI	(1.7 x 1.0)
1777*	CP(A&P)-PO	SI	(1.5 x 0.9)
1717*	PP-LB-Ck	SI	(2.0 x 1.0)
1600	PP-LB	SI	(1.7 x 1.0)

PBL = 1745

<u>FAPT</u>			
2125	CP(A&P)-PO	SI	(1.6 x 1.0)
2082	CP(A&P)-PO	SI	(1.8 x 1.0)
1980*	CP(A&P)-PO	SI	(1.9 x 1.0)
1975*	CP(A)-PH	SI	(1.8 x 1.0)
1910	PP-LB-Ck	SI	(1.8 x 0.9)

PBL = 1980

**D. Firing vs Plate No. 21 (311 Bhn) at 55° Obliquity**

<u>AP</u>			
2645	CP(A&P)-PO	BI 1/3-Sh-Fr-LS	(2.0 x 1.0)
2540	CP(A&P)-PO	BI 1/4-Sh-Fr-LS	(1.8 x 1.0)
2518*	CP(A&P)-PO	Sh-Fr-LS	(1.6 x 1.0)
2465*	PP-LB-Ck	BI 1/3-Sh-Fr-LS	(1.7 x 1.0)
2416	PP-LB-Ck	Sh-Fr-LS	(1.9 x 0.9)
2274	PP-MB	Sh-Fr-LS	(1.8 x 0.9)

PBL = 2490

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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## III. Firing against 5/8 Inch Homogeneous Armor (Cont'd)

## D. Firing vs Plate No. 21 (311 Bhn) at 55° Obliquity (Cont'd)

<i>Striking Velocity (fps)</i>	<i>Plate</i>	<i>Results Projectile</i>	<i>Scoop</i>
<u>FAP</u>			
2353	CP(A&P)-PO	SI	(2.4 x 1.1)
2313*	CP(A&P)-PO	SI	(2.3 x 1.0)
2264*	CP(A)-Ph	SI	(2.3 x 1.0)
2163	PP-LB-Ck	SI	(2.3 x 1.0)

PBL = 2290

<u>FAPT</u>			
2408	CP(A&P)-PO	SI	(2.3 x 1.0)
2315*	CP(A&P)-PO	SI	(2.2 x 1.0)
2286*	CP(A)-PS	SI	(2.1 x 1.0)
2286	PP-LB-Ck	BI 3/5-Fr	(2.3 x 1.0)
2200	PP-LB	SI	(2.1 x 1.1)

PBL = 2300

## E. Firing vs Plate No. 21 (311 Bhn) at 60° Obliquity

<u>AP</u>			
2864	CP(A&P)-PO	Sh-Fr-LS	(2.2 x 1.0)
2845	CP(A&P)-PO	Sh-Fr-LS	(2.2 x 1.0)
2808*	CP(A&P)-PO	BI 2/5-Sh-Fr-LS	(2.3 x 1.0)
2764*	PP-LB-Ck	Sh-Fr-LS	(2.3 x 0.9)
2640 (Fig 14)	PP-LB-Ck	Sh-Fr-LS	(2.3 x 0.9)

PBL = 2785

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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**III. Firing against 5/8 Inch Homogeneous Armor (Cont'd)**

**E. Firing vs Plate No. 21 (311 Bhn) at 60° Obliquity (Cont'd)**

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results</u>	<u>Projectile</u>	<u>Scoop</u>
<u>FAP</u>				
2695 (Fig 14)	CP(A&P)-PO	SI		(2.5 x 1.1)
2615 (Fig 14)	CP(A&P)-PO	SI		(2.8 x 1.1)
2588*	CP(A&P)-PO	SI		(2.8 x 1.1)
2534*	CP(A)-FH	SI		(2.8 x 1.1)
2506	PP-LB	SI		(2.6 x 1.1)
2345	PP-SB	SI		(2.8 x 1.1)
PBL = 2560				

<u>FAPT</u>			
2702	CP(A&P)-PO	BI 2/5-Fr	(2.7 x 1.1)
2663	CP(A&P)-PO	SI-Ck	(2.6 x 1.0)
2628	CP(A)-PO	Fr	(2.8 x 1.1)
2617*(Fig 14)	CP(A&P)-PO	SI-Ck	(2.6 x 1.1)
2589*	PP-LB-Ck	SI-Ck	(2.8 x 1.1)
2577	CP(A)-PH	SI-Ck	(2.6 x 1.0)
2505	CP(A&P)-PO	SI	(2.6 x 1.0)
2482	CP(A)-PS	SI	(2.6 x 1.0)
2400	PP-LB-Ck	SI-Ck	(2.6 x 1.0)
PBL = 2605			

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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**III. Firing against 5/8 Inch Homogeneous Armor (Cont'd)**

**F. Firing vs Plate No. 22 (302 to 321 Bhn) at 70° Obliquity**

<i>Striking Velocity (fps)</i>	<i>Plate</i>	<i>Results Projectile</i>	<i>Scoop</i>
<u>AP</u>			
3630	CP(A&P)-PO	Sh-Fr-LS	(2.6 x 1.1)
3605*	CP(A&P)-PO	Sh-Fr-LS	(2.5 x 1.1)
3602*	PP-LB-Ck	Sh-Fr-LS	(2.9 x 1.1)
3591	PP-LB-Ck	Sh-Fr-LS	(2.8 x 1.0)
3505	PP-LB	Bl 1/3-Sh-Fr-LS	(3.0 x 1.0)
3403	PP-MB	Sh-Fr-LS	(2.5 x 0.8)
3303	PP-MB	Sh-Fr-LS	(2.7 x 0.9)

PBL = 3605

		<u>FAP</u>	
3463	PP-MB	Sh-Fr-LS	(2.3 x 1.0)
3300	PP-LB	Sh-Fr-LS	(2.4 x 1.1)
3055	PP-SB	Sh-Fr-LS	(2.3 x 0.9)

PBL > 3465

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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**III. Firing against 5/8 Inch Homogeneous Armor (Cont'd)**

**F. Firing vs Plate No. 22 (302 to 321 Bhn) at 70° Obliquity (Cont'd)**

<i>Striking Velocity (fps)</i>	<i>Plate</i>	<i>Results Projectile</i>	<i>Scoop</i>
<b>FAPT</b>			
3382	CP(A&P)-PO	Sh-Fr-LS	(2.7 x 1.2)
3315	CP(A&P)-PO	Sh-Fr-LS	(2.4 x 1.2)
3240*	CP(A&P)-PO	Sh-Fr-LS	(2.3 x 1.1)
3219*	PP-LB	Sh-Fr-LS	(2.9 x 1.1)
3214	PP-PS	Sh-Fr-LS	(2.4 x 1.2)
3145	PP-PS	Sh-Fr-LS	(2.5 x 1.0)
2994	PP-PS	Sh-Fr-LS	(2.3 x 1.1)
2884	PP-SB	SI	(3.4 x 1.0)

PBL = 3230

**IV. Firing against 3/4 Inch Homogeneous Armor**

**A. Firing vs Plate No. 43 (302 Bhn) at 30° Obliquity**

<b>AP</b>			
2432	CP(NI)-EP	SI	(1.5 x 1.2)
2358	CP(A&P)-PO	BI 3/5-Sh-Fr-LS	(1.5 x 1.2)
2320*(Fig 4)	CP(A&P)-PO	Sh-Fr-LS	(1.9 x 1.2)
2271*	PP-PS	Sh-Fr-LS	(1.9 x 1.2)
2167	PP-LB-Ck	Sh-Fr-LS	(2.0 x 1.2)
2027 (Fig 4)	PP-MB	Sh-Fr-LS	(2.0 x 1.1)
1933 (Fig 4)	CP(NF)-BPO	BI 3/5-NI 2/5-Fr	(1.6 x 1.1)
1825*(Fig 4)	CP(A&P)-BPO	SI	(1.5 x 1.1)
1775*(Fig 4)	CP(A)-EPS	SI	(1.7 x 1.0)

PBL = 1800; 2295

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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## IV. Firing against 3/4 Inch Homogeneous Armor (Cont'd)

## A. Firing vs Plate No. 43 (302 Bhm) at 30° Obliquity (Cont'd)

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>FAP</u>			
1700	CP(A&P)-PO	SI	(1.4 x 1.1)
1666*	CP(A&P)-PO	SI	(1.4 x 1.0)
1638*	PP-LB-Ck	SI	(1.5 x 1.1)
1603	PP-LB-PS	SI	(1.3 x 1.0)
PBL = 1650			

		<u>FAPT</u>	
1945	CP(A&P)-PO	SI	(1.9 x 1.0)
1866	CP(A&P)-PO	SI	(1.8 x 1.0)
1794*	CP(A&P)-PO	SI	(1.6 x 1.1)
1781*	PP-MB	SI	(2.2 x 1.1)
1730	PP-MB	SI	(1.6 x 1.0)
PBL = 1790			

## B. Firing against Plate No. 43 (302 Bhm) at 45° Obliquity

		<u>AP</u>	
2621	CP(A&P)-PO	BI 1/3-Sh-Fr-LS	(1.7 x 1.3)
2570	CP(A)-Ph	Sh-Fr-LS	(1.6 x 1.2)
2508	CP(A&P)-PO	Sh-Fr-LS	(1.5 x 1.0)
2449*	CP(A&P)-PO	BI 2/5-Sh-Fr-LS	(1.4 x 1.2)
2402*	PP-LB	BI 2/5-Sh-Fr-LS	(1.5 x 1.1)
2342	PP-MB	Sh-Fr-LS	(1.5 x 1.2)
2200	PP-SB	Sh-Fr-LS	(1.4 x 1.2)
PBL = 2425			

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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IV. Firing against 3/4 Inch Homogeneous Armor (Cont'd)

E. Firing against Plate No. 43 (302 Bhn) at 45° Obliquity (Cont'd)

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>FAP</u>			
2346	CP(A&P)-PO	SI -Ck	(1.9 x 1.1)
2225	CP(A&P)-PO	SI	(2.0 x 1.1)
2118*	CP(A&P)-PO	SI	(1.9 x 1.1)
2053*	PP-LB	SI	(1.9 x 1.1)
2005	PP-LB	SI	(1.9 x 1.1)

PBL = 2085

<u>FAPT</u>			
2612	CP(N1)-PO	SI	(1.7 x 1.1)
2438	CP(A&P)-PO	SI	(1.7 x 1.0)
2325	CP(A&P)-PO	SI	(1.7 x 1.1)
2184*	CP(A&P)-PO	SI	(2.0 x 1.1)
2159*	CP(A)-PS	SI	(1.9 x 1.0)
2150	PP-MB	SI	(2.1 x 1.1)
2072	PP-MB	SI	(2.1 x 1.2)

PBL = 2170

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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IV. Firing against 3/4 Inch Homogeneous Armor (Cont'd)

C. Firing vs Plate No. 34 (302 Bhn) at 55° Obliquity

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>AP</u>			
3067	CP(A&P)-PO	Sh-Fr-LS	(1.9 x 1.2)
3012	CP(A&P)-PO	Sh-Fr-LS	(1.9 x 1.3)
2983*	CP(A&P)-PO	BI-Sh-Fr-LS	(1.9 x 1.2)
2925*	PP-LB-Ck	Sh-Fr-LS	(1.9 x 1.2)
2830	PP-LB	Sh-Fr-LS	(2.2 x 1.3)
2657	PP-MB	Sh-Fr-LS	(2.0 x 1.2)

PBL = 2955

		<u>FAP</u>	
3295**	CP(A&P)-PO	BI 1/3-Sh-Fr-LS	(2.0 x 1.2)
3195**	PP-LB	BI 1/2-Sh-Fr-LS	(2.3 x 1.4)
3140+	PP-LB-Ck	Sh-Fr-LS	(2.0 x 1.4)
2925	PP-LB	BI 1/4-Sh-Fr-LS	(2.1 x 1.3)
2890	PP-MB	Sh-Fr-LS	(2.1 x 1.3)
2835	PP-MB	Sh-Fr-LS	(2.1 x 1.3)
2815	PP-LB-Ck	Sh-Fr-LS	(1.8 x 1.5)
2805	PP-LB-Ck	SI-Ck	(2.5 x 1.2)
2660	PP-LB	SI	(2.7 x 1.2)
2535	PP-MB	SI	(2.7 x 1.2)

PBL <sup>a</sup> = 3245

\*Firing vs Plate No. 38 (293 to 302 Bhn).

\*\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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IV. Firing against 3/4 Inch Homogeneous Armor (Cont'd)

C. Firing vs Plate No. 34 (302 Bhn) at 55° Obliquity (Cont'd)

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>FAPT</u>			
2885	CP(A&P)-IO	SI	(2.5 x 1.0)
2800*	CP(A&P)-PO	BI 1/3-Fr	(2.5 x 1.1)
2760*	PP-LB	SI-Ck	(2.5 x 1.1)
2705	CP(A)-PS	Fr	(2.6 x 1.2)
2655	PP-LB	BI 3/4-Fr	(2.6 x 1.1)

PHL = 2780

D. Firing vs Plate No. 34 (302 Bhn) at 60° Obliquity

		<u>AP</u>	
3235	CP(A&P)-PO	Sh-Fr-LS	(2.1 x 1.2)
3213*	CP(A&P)-PO	Sh-Fr-LS	(2.3 x 1.1)
3170*	PP-LB-Ck	Sh-Fr-LS	(2.3 x 1.3)
3155	PP-LB-Ck	Sh-Fr-LS	(2.4 x 1.2)
3000	PP-LB	Sh-Fr-LS	(2.0 x 1.1)

PHL = 3190

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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## IV. Firing against A/4 Inch Homogeneous Armor (Cont'd)

## D. Firing vs Plate No. 34 (302 Bhn) at 60° Obliquity (Cont'd)

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>FAP</u>			
3420	PP-LB	BI 2/5-Sh-Fr-LS	(2.3 x 1.3)
3400	PP-LB-Ck	BI 1/3-Sh-Fr-LS	(2.4 x 1.3)
3304	PP-LB	BI 2/5-Sh-LS	(1.9 x 1.1)
3051	PP-SB	Sh-Fr-LS	(2.1 x 1.3)
2938	PP-MB	Sh-Fr-LS	(2.1 x 1.3)
2905	PP-MB	SI-Ck	(3.1 x 1.2)
2848	PP-MB	BI 2/5-Sh-Fr-LS	(2.4 x 1.2)
2835	PP-MB	SI	(3.0 x 1.2)
2780	PP-MB	SI	(3.1 x 1.1)
PBL > 3420			

<u>FAPT</u>			
3330	CP(A&P)-PO	Sh-Fr-LS	(2.6 x 1.3)
3256	CP(NS)-PO	Sh-Fr-LS	(2.2 x 1.5)
3190	CP(NS)-PO	Sh-Fr-LS	(2.2 x 1.3)
3100*	CP(NS)-PO	Sh-Fr-LS	(2.1 x 1.3)
3032*	CP(A)-PH	SI-Ck	(2.8 x 1.2)
2950	PP-LB	SI-Ck	(3.0 x 1.2)

PBL = 3065

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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V. Firing against 7/8 Inch Homogeneous Armor

A. Firing vs Plate No. 48 (302 to 311 Bhn) at 30° Obliquity

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>AP</u>			
2830	CP(NS)-PO	Sh-Fr-LS	(1.6 x 1.5)
2778	CP(NS)-PO	Sh-Fr-LS	(1.6 x 1.6)
2717	CP(A&P)-PO	BI 2/5-Sh-Fr-LS	(1.5 x 1.4)
2690	CP(A)-PS	BI 2/5-Sh-Fr-LS	(1.5 x 1.3)
2674	CP(A&P)-PO	Sh-Fr-LS	(1.5 x 1.4)
2602*	CP(A&P)-PO	BI 2/3-Sh-Fr-LS	(1.5 x 1.2)
2543*	PP-LB-Ck	BI 2/3-Sh-Fr-LS	(1.5 x 1.4)
2457	PP-LB	BI 2/3-Sh-Fr-LS	(1.5 x 1.3)
2303	PP-SB	Sh-Fr-LS	(1.4 x 1.4)
2121(Fig 13)	PP-SB	Sh-Fr-LS	(1.5 x 1.2)

PBL = 2570

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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## V. Firing against 7/8 Inch Homogeneous Armor (Cont'd)

## A. Firing vs Plate No. 48 (302 to 311 Bhn) at 30° Obliquity (Cont'd)

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>FAP</u>			
3182 <sup>+</sup>	CP(A&P)-PO	Sh-Fr-LS	(1.9 x 1.7)
3180 <sup>++*</sup>	CP(A&P)-PO	Sh-Fr-LS	(1.8 x 1.5)
3098 <sup>++*</sup>	PP-LB-Ck	Sh-Fr-LS	(1.8 x 1.5)
3068 <sup>+</sup>	PP-LB-PS	Sh-Fr-LS	(1.7 x 1.5)
2116(Fig 10)	PP-SB	BI 2/3-Sh-Fr-LS	(1.3 x 1.4)
1980(Fig 10)	PP-SB	BI 2/3-Sh-Fr-LS	(1.4 x 1.5)
1865(Fig 10)	PP-MB	BI 2/3-Fr	(1.5 x 1.0)
1835(Fig 10)	PP-LB	SI	(1.4 x 1.0)
1585	PP-MB	SI	(1.4 x 1.2)

$$PBL \stackrel{a}{=} 3140$$

		<u>FAPT</u>	
2443	CP(NS)-PO	Sh-Fr-LS	(2.0 x 1.0)
2168	CP(A&P)-PO	BI 3/4-Sh-Fr-LS	(1.9 x 1.0)
2153*(Fig 13)	CP(A&P)-PO	BI 2/3-Fr-LS	(1.7 x 1.1)
2100*	PP-LB-Ck	BI 2/3-Fr-LS	(1.9 x 1.2)
2043	PP-LB-Ck	Fr	(1.9 x 1.1)
1885	PP-SB	BI 1/3-Fr	(2.1 x 1.2)

$$PBL = 2125$$

\*Firing vs Plate No. 50 (302 to 311 Bhn).

\*\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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V. Firing against 7/8 Inch Homogeneous Armor (Cont'd)

E. Firing vs Plate No. 47 (302 to 306 Bhv) at 45° Obliquity

<i>Striking Velocity (fps)</i>	<i>Plate</i>	<i>Results Projectile</i>	<i>Sccop</i>
<u>AP</u>			
3040	CP(NS)-PO	BI 1/2-Sh-LS	(1.7 x 1.4)
3038	CP(NS)-PO	Sh-LS	(1.6 x 1.4)
3018*	CP(A&P)-PO	Sh-Fr-LS	(1.7 x 1.3)
3000*	PP-LB-PS	BI 2/5-Sh-Fr-LS	(1.7 x 1.3)
2980	PP-LB-Ck	Sh-Fr-LS	(1.8 x 1.3)
2810	PP-LB-Ck	Sh-Fr-LS	(1.9 x 1.3)
2575	PP-MB	BI 1/4-Sh-Fr-LS	(1.7 x 1.5)

PBL = 3010

		<u>FAP</u>	
3495+*	CP(A&P)-PO	Sh-Fr-LS	(1.8 x 1.3)
3460+*	PP-LB-PS	Sh-Fr-LS	(1.8 x 1.4)
3235+	PP-LB-Ck	BI 2/5-Sh-Fr-LS	(1.8 x 1.5)
3135+	PP-LB-Ck	BI 2/5-Sh-Fr LS	(1.7 x 1.4)
2596	PP-SB	Sh-Fr-LS	(1.9 x 1.6)
2571(Fig 11)	PP-SB	Sh-Fr-LS	(1.6 x 1.5)
2553(Fig 11)	PP-LB-Ck	SI	(2.4 x 1.1)
2546	PP-SB	Sh-Fr-LS	(1.7 x 1.6)
2441	PP-LB	SI-Ck	(2.2 x 1.2)

PBL <sup>a</sup> = 3480

+Firing vs Plate No. 50 (302 to 311 Bhv).

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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## V. Firing against 7/8 Inch Homogeneous Armor (Cont'd)

## B. Firing vs Plate No. 47 (302 to 306 Bhn) at 45° Obliquity (Cont'd)

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>FAPT</u>			
2960 (Fig 12)	CP(NS)-PO	BI 1/3-Sh-Fr-LS	(1.9 x 1.2)
2780 (Fig 12)	CP(A&P)-PO	BI 1/2-Sh-Fr-LS	(1.3 x 1.2)
2690 (Fig 12)	CP(A&P)-PO	Fr-Sh	(1.3 x 1.2)
2600 (Fig 12)	CP(A&P)-PO	SI	(1.9 x 1.1)
2545*	CP(A&P)-PO	Fr-Sh	(2.0 x 1.2)
2527*	CP(A)-PS	SI	(2.0 x 1.1)
2450	PP-LB-Ck	Fr	(2.0 x 1.2)
PBL = 2535			

## C. Firing vs Plate No. 47 (302 to 306 Bhn) at 55° Obliquity

		<u>AP</u>	
3543	CP(NS)-PO	Sh-Fr-LS	(2.1 x 1.6)
3498*(Fig 16)	CP(NS)-PO	BI 1/2-Sh-Fr-LS	(2.3 x 1.5)
3467*	CP(A)-PH	BI 1/3-Sh-Fr-LS	(2.2 x 1.4)
3442 (Fig 16)	CP(A)-PH	Sh-Fr-LS	(2.0 x 1.5)
3405	PP-LB-Ck	Sh-Fr-LS	(2.2 x 1.4)
3393	PP-LB-Ck	Sh-Fr-LS	(2.2 x 1.4)
3333	PP-MB	Sh-Fr-LS	(2.5 x 1.3)
3298	PP-LB-Ck	BI 1/3-Sh-Fr-LS	(2.0 x 1.4)
3298	CP(A&P)-PO	BI 1/3-Sh-LS	(2.0 x 1.5)
3130 (Fig 15)	PP-MB	Sh-Fr-LS	(2.2 x 1.3)
2827	PP-SB	BI 1/3-Sh-Fr-LS	(1.9 x 1.3)
PBL = 3480			

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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V. Firing against 7/8 Inch Homogeneous Armor (Cont'd)

C. Firing vs Plate No. 47 (302 to 306 Bhn) at 55° Obliquity (Cont'd)

<i>Striking Velocity (fps)</i>	<i>Plate</i>	<i>Results Projectile</i>	<i>Scoop</i>
<u>FAP</u>			
3396 <sup>+</sup>	PP-MB	BI 1/4-Sh-Fr-LS	(2.1 x 1.3)
PBL > 3400			
<u>FAPT</u>			
3330	CP(A&P)-PO	Sh-Fr-LS	(2.2 x 1.4)
3120 (Fig 15)	CP(A&P)-PO	Sh-Fr-LS	(2.2 x 1.3)
3075*	CP(A&P)-PO	Sh-Fr-LS	(1.9 x 1.3)
3029*(Fig 16)	PP-LB-Ck	Sh-Fr-LS	(2.7 x 1.2)
3003	PP-MB	BI 1/3-Sh-Fr-LS	(2.3 x 1.1)
2966	PP-LB	SI-Ck	(2.9 x 1.3)
2872	PP-LB-Ck	SI-Ck	(2.6 x 1.1)
2844	PP-MB	SI-7/8-Fr	(2.8 x 1.2)
PBL = 3050			

D. Firing vs Plate No. 48 (302 to 311 Bhn) at 60° Obliquity

		<u>AP</u>	
3674*	CP(A&P)-PO	Sh-Fr-LS	(2.3 x 1.4)
3667*	CP(A)-PS	BI 1/3-Sh-Fr-LS	(2.4 x 1.4)
3667	PP-LB	BI 1/3-Sh-Fr-LS	(2.6 x 1.5)
3663	PP-LB-Ck	BI 2/5-Sh-Fr-LS	(2.3 x 1.4)
3632	PP-LB	Sh-Fr-LS	(2.5 x 1.5)
3610	PP-PS	BI 1/3-Sh-Fr-LS	(2.2 x 1.2)
PBL = 3670			

\*Firing vs Plate No. 50 (302 to 311 Bhn).

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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V. Firing against 7/8 Inch Homogeneous Armor (Cont'd)

D. Firing vs Plate No. 48 (302 to 311 Bhn) at 60° Obliquity (Cont'd)

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>FAPT</u>			
3672*	CP(A&P)-FO	Sh-Fr-LS	(2.5 x 1.4)
3667*	PP-LB-Ck	Sh-Fr-LS	(2.5 x 1.5)
3633	CP(A)-PS	Sh-Fr-LS	(2.4 x 1.3)
3612	PP-LB-Ck	Sh-Fr-LS	(2.2 x 1.4)
3570	PP-LB-Ck	Sh-Fr-LS	(2.3 x 1.5)
3438	PP-LB-Ck	Sh-Fr-LS	(2.1 x 1.2)
3250	PP-LB	Sh-Fr-LS	(2.4 x 1.2)

PBL = 3670

VI. Firing against 1 Inch Homogeneous Armor

A. Firing vs Plate No. 26 (302 Bhn) at 0° Obliquity

	<u>AP</u>	
2191	CP(NI)-BP-PP	SI
2085	CP(NI)-BP-PP	SI
2080*	CP(NI)-BP-PP	SI
2032*	CP(A)-Ck-PP	SI
1935	CP(A)-Ck-PP	SI

PBL = 2055

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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VI. Firing against 1 Inch Homogeneous Armor (Cont'd)

A. Firing vs Plate No. 26 (302 Rhn) at 0° Obliquity (Cont'd)

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>FAP</u>			
3410	CP(NS)-PO	Sh-Fr-LS	
3320*	CP(NS)-FO	Sh-Fr-LS	
3210*	PP-LB-PS	Sh-Fr-LS	
2888	PP-LB-Ck	Sh-Fr-LS	
<u>PBL = <sup>a</sup> 3265</u>			

		<u>FAPT</u>
3225	CP(NS)-PO-FP	Bl 2/3-Sh-Fr-LS
3085	CP(NS)-PO-FP	Sh-Fr-LS
2771	CP(NS)-PO	Sh-Fr-LS
2542	CP(NS)-PO	SI 7/8-Sh
2165	CP(NI)-BP-FP	SI
2137*	CP(NI)	SI
2080*	CP(A)-BPS	SI
2028	CP(A)-Ck	SI
1994	PP-LB-Ck-FP	SI
1745	PP-MB-FP	SI

PBL = 2110

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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**VI. Firing against 1 Inch Homogeneous Armor (Cont'd)**

**B. Firing vs Plate No. 26 (302 bhn) at 45° Obliquity**

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>AP</u>			
3582	CP(NS)-PO	Sh-Fr-LS	(2.0 x 1.6)
3461*	CP(NS)-PO	BI 1/3-Sh-Fr-LS	(1.9 x 1.7)
3406*	PP-VLB-Ck	BI 2/5-Sh-Fr-LS	(1.9 x 1.7)
3346	PP-VLB-Ck	Sh-Fr-LS	(1.8 x 1.6)
3245	PP-LB-Ck	Sh-Fr-LS	(1.8 x 1.6)
PBL = 3435			

		<u>FRST</u>	
2940	CP(NS)-PO	Sh-Fr-LS	(2.0 x 1.3)
2856*	CP(A&F)-PO	BI 1/2-Sh-Fr-LS	(2.0 x 1.3)
2794*	PP-PS	BI 1/3-Sh-Fr-LS	(2.0 x 1.2)
2727	PP-LB-PS	BI 9/10-Fr	(2.0 x 1.2)
PBL = 2825			

**C. Firing vs Plate No. 26 (302 Bhn) at 55° Obliquity**

		<u>AP</u>	
3645	PP-LB-Ck	Sh-Fr-LS	(2.4 x 1.5)
3612	PP-LB-Ck	BI 1/3-Sh-Fr-LS	(2.2 x 1.5)
3560	PP-LB-Ck	Sh-Fr-LS	(2.1 x 1.5)
PBL > 3645			

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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VI. Firing against 1 Inch Homogeneous Armor (Cont'd)

C. Firing vs Plate No. 26 (302 Bhn) at 55° Obliquity (Cont'd)

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>FAPT</u>			
3665 <sup>++</sup>	PP-LB-BSS	Sh-Fr-LS	(2.4 x 1.6)
3656 <sup>++</sup>	CP(A&P)-PO	Sh-Fr-LS	(2.4 x 1.5)
3645 <sup>++</sup>	CP(A&P)-PO	Sh Fr-LS	(2.3 x 1.4)
3605 <sup>++</sup>	PP-LB-Ck	Sh-Fr-LS	(2.2 x 1.5)
3603 <sup>++</sup>	PP-LB	Sh-Fr-LS	(2.2 x 1.5)
3585 <sup>++</sup>	CP(A&P)-PO	Sh-Fr-LS	(2.3 x 1.4)
3524	PP-LB-Ck	Sh-Fr-LS	(2.1 x 1.5)
3423	PP-LB-Ck	Sh-Fr-LS	(1.9 x 1.4)
3365	PP-LB-Ck	Sh-Fr-LS	(2.1 x 1.)
3183	PP-SB	Sh-Fr-LS	(2.1 x 1.6)

FBL <sup>a</sup> = 3625

<sup>++</sup>Velocities averaged to determine the protection ballistic limit and specific limit energy.

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VII. Firing against 1 1/8 Inch Homogeneous Armor

A. Firing vs Plate No. 15 (311 to 321 Bhn) at 30° Obliquity

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>AP</u>			
3405	CP(A&P)-BSO	Sh-Fr-LS	(1.8 x 1.7)
3340*	CP(A&P)-BSO	Sh-Fr-LS	(1.6 x 1.8)
3297*	PP-LB-BSS	Sh-Fr-LS	(1.6 x 1.6)
3273	PP-LB-BSS	BI 2/5-Sh-Fr-LS	(1.8 x 1.6)
3228	PP-LB	BI 1/2-Sh-Fr-LS	(1.7 x 1.7)
3046	PF-LB	BI 1/4-Sh-Fr-LS	(1.7 x 1.7)
2503	PF-SB	Sh-Fr-LS	(1.4 x 1.4)

PEL = 3320

<u>FAPT</u>			
3220	CP(A&P)-BSO	Sh-Fr-LS	(1.7 x 1.7)
3128*	CP(A&P)-BSO	Sh-Fr-LS	(1.7 x 1.5)
3085*	PF-LB-BSS	Sh-Fr-LS	(1.7 x 1.7)
3060	PP-LB-BSS	Sh-Fr-LS	(1.7 x 1.6)
3015	PP-LB	Sh-Fr-LS	(1.8 x 1.7)
2955	PP-MR	Sh-Fr-LS	(1.5 x 1.5)
2705	PP-MB	Sh-Fr-LS	(1.6 x 1.4)

PEL = 3105

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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VII. Firing against 1 1/8 Inch Homogeneous Armor (Cont'd)

B. Firing vs Plate No. 15 (311 to 321 Bhn) at 45° Obliquity

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
<u>AFT</u>			
3678	CP(A&P)-BS	Sh-Fr-LS	(1.9 x 1.7)
3660*	CP(NS)-BS	BI 2/5-Sh-Fr-LS	(1.8 x 1.5)
3655*	PP-LB-BSS	Sh-Fr-LS	(2.0 x 1.6)
3636	PP-LB	Sh-Fr-LS	(2.1 x 1.6)
3629	PP-LB	BI 1/4-Sh-Fr-LS	(2.0 x 1.6)
3607	PP-LB	Sh-Fr-LS	(1.9 x 1.7)
3586	PP-LB-BSS	BI 1/3-Sh-Fr-LS	(1.8 x 1.6)
3477	PP-LB	BI 1/2-Sh-Fr-LS	(1.8 x 1.6)

PBL = 3660

<u>FAPT</u>			
3650	CP(A&P)-BS	Sh-Fr-LS	(2.0 x 1.6)
3590*	CP(A&P)-BS	Sh-Fr-LS	(2.1 x 1.5)
3557*	PP-LB-PS	BI 1/3-Sh-Fr-LS	(2.1 x 1.5)
3541	PP-LB-PS	Sh-Fr-LS	(2.1 x 1.5)

PRL = 3575

\*Bracketing velocities used to calculate protection ballistic limits and specific limit energies.

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VIII. Firing against 1 3/8 Inch Homogeneous Armor

Firing vs Plate No. 7 (310 Bhn) at 0° Obliquity

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results</u>	<u>Scoop</u>
<u>AP</u>			
3631 <sup>++</sup>	PP-LB-PS-FPO	BI 1/3-Sh-LS	
3596 <sup>+*</sup>	CP(A&P)-PO	BI 2/5-Sh-LS	
3586 <sup>+</sup>	PP-VLB-FPO	BI 2/5-Sh-LS	
3545 <sup>+</sup>	PP-VLB-IP0	BI 1/3-Sh-LS	
3427 <sup>+</sup>	PP-LB-Ck-FPO	BI 1/3-Sh-LS	
3214	PP-MB	Sh-LS	
3120	PP-MB	Sh-Fr-LS	
3046	CP(NI)-BSO-FPO	SI-Fr-at Nose	
2995	CP(NI)-BSO-FP	SI-Fr-at Nose	
2822	CP(N)-BSO-FP	SI-Fr-at Nose	
2737	PP-SB	BI 1/3-Sh-Fr	
2721 <sup>*</sup>	CP(A&P)BSO-FP	SI 7/8-Fr	
2669 <sup>*</sup>	CP(A)-Ck-FP	SI	
2603	PP-LB-Ck-FP	SI	

PNL = 2695; 3610

<sup>+</sup>Firing vs Plate No. 8 (311 to 321 Bhn).

<sup>\*</sup>Bracketing velocities used to determine protection ballistic limits and specific limit energies.

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## VIII. Firing against 1 3/8 Inch Homogeneous Armor (Cont'd)

## Firing vs Plate No. 7 (310 Pbm) at 0° Obliquity (Cont'd)

<u>Striking Velocity (fps)</u>	<u>Plate</u>	<u>Results Projectile</u>	<u>Scoop</u>
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FAP

3215	PP-SB	Sh-Fr-LS
2975	PP-SB	Sh-Fr-LS
2695	PP-VSB	Sh-Fr-LS
2250	PP-NB	Sh-Fr-LS

PBL &gt; 3215

FAPT

3640	CP(A&P)-BSO	BI 1/3-Sh-Fr-LS
3640	CP(A&P)-BSH	Sh-Fr-LS
3625*	CP(A&P)-BSO	BI 1/3-Sh-Fr-LS
3605*	PP-LB-BSS	Sh-Fr-LS
3552	PP-LB	Sh-Fr-LS
3375	PP-LB-FSO	Sh-Fr-LS
3334	PP-LB	Sh-Fr-LS
3144	PP-MB-FSO	Sh-Fr-LS
3013	PP-SB	Sh-Fr-LS
2713	PP-SB-FPO	Sh-Fr-LS
2477	PP-SB-FSO	Sh-Fr-LS
2387	PP-SB-FSO	Sh-Fr-LS
2271	PP-SB-FSO	Sh-Fr-LS
2225	PP-SB	SI
1978	PP-SB	SI

PBL = 3615

\*Bracketing velocities used to calculate protection ballistic limit and specific limit energies.

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- 1 - Commanding General  
Aberdeen Proving Ground  
Maryland  
Attn: Ball Res Lab
- 2 - Attn: Arms & Amm
- 1 - Commandant  
Ordnance School  
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Attn: Tech Intell Br
- 1 - Attn: ORDMS-RC
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- 1 - Commandant  
US Naval Proving Ground  
Dahlgren, Va.  
Attn: Terminal Ball Lab